A MINE EXPLOSION

Charge, 276 lbs. Mortar Powder. Mine resting on bottom in water 10 feet deep. Height of Jet about 280 feet.

TORPEDOES

AND

TORPEDO WARFARE:

CONTAINING A

COMPLETE ACCOUNT OF THE

PROGRESS OF SUBMARINE WARFARE;

ALSO A

DETAILED DESCRIPTION OF MATTERS APPERTAINING THERETO, INCLUDING THE LATEST IMPROVEMENTS.

BY

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WITH EIGHTY-THREE FULL-PAGE ILLUSTRATIONS, DIAGRAMS, &c.

SECOND EDITION.

PORTSMOUTH:
GRIFFIN & CO., 2, THE HARD,
(Publishers by Appointment to Her Majesty, and H.R.H. the Duke of Edinburgh)
LONDON AGENTS: SIMPKIN, MARSHALL & CO.

1889.

PREFACE.

I TRUST that this new edition of my book may meet with the same kind and lenient treatment so generously accorded to its predecessor, and that my endeavour to bring the history of submarine warfare up to date may prove of some use to those who are interested in this subject, but to whom the more valuable official publications are sealed books.

I beg to tender my best thanks to all from whom I have obtained information, or who have otherwise aided me in my work, among whom I may mention the following:—

Messrs. Siemens Bros., Mr. Gray (Silvertown Telegraph Works Co.), Mr. Gibbons (Messrs. Latimer Clark, Muirhead and Co.), Capt. C. A. McEvoy, Mr. Th. Nordenfelt, Mr. Yarrow, Capt. J. A. Howell, U.S.N., Mr. J. P. Holland, Mons. G. Canet (Forges et Chantiers de la Méditerranée), Electrical Power Storage Co., General Berdan, Mons. Augustin Normand, and Mons. F. Schibau.

C. SLEEMAN.

LONDON, JAN. 1889.

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THE *Early History of Submarine Warfare.*—The history of the submarine mine and the torpedo, from their earliest conception to the time of the American Civil War (1861), will be found to consist in the main of numerous, more or less, extravagant accounts of the wonderful effects produced by the explosion of a charge of gunpowder in actual contact with the bottom of some old hulk, the resultant effect in wonder and astonishment produced on the spectators being proportionate to the size of the charge, and the degree of rottenness of the hulk's timbers, varied occasionally by the illusion practised on the explosion, if the charge having been ignited, through some means or other, by an operator stationed at some distance away from the actual scene of the explosion.

Torpedoes and mines, or infernal machines as they were then more generally termed, were certainly used in naval wars previous to 1861, but the materials at the disposal of the torpedoists of that time, for constructing such machines, were so exceedingly crude, and the knowledge of their nature and of their action was so limited, while in addition to these causes they were then looked upon as abominable and unclean things, it is not to be wondered at that the few attempts to utilise them, of which there is any record, should have resulted in complete failure: consequently this portion of what may be termed the infantile life of the torpedo and the submarine mine does not call for any special consideration on the part of the knowledge-seeking torpedoist of the present day, seeing that it affords no useful lessons as to the applicability of these implements for actual warfare.

Submarine Mines and Torpedoes in the American Civil War.—In the American Civil war, however, the Southerners, owing to their holding a considerable extent of sea coast (including some important harbours), and to the absence of even a "paper" navy wherewith to defend it against the numerically powerful fleets at the command of their opponents, were forced to call to their aid these much-talked-of and abused instruments; and it is an historical fact that the wonderful ingenuity displayed by the Confederates in devising and constructing self-acting and controlled submarine mines in great varieties, as well as submarine and surface spar torpedo boats, was one, if not the principal cause of the protracted nature of the terrible struggle between the northern and southern States of America. Towards the end of the war, the Federals in self-defence were also forced to resort to the use of the spar torpedo, so that it may be said that the submarine mine and the torpedo in the course of this great struggle lept at one bound from the condition of theory and experiment, to become accepted once for all as practical and valuable factors for offence and defence. The mining and the torpedo operations executed during this war were attended with such unprecedented and unexpected success, attested by the numerous ships, either sunk or disabled by their action, by the immunity from attack of harbours known, or supposed to be mined, and by the many repulses met with by the Federals in their frequent attempts to capture the harbours of the Southerners, that the submarine mine and the torpedo then and there justly received the seal of international authority, as legitimate weapons of naval warfare.

The torpedo and mine work, executed during the American Civil War, is well worthy of close study by all those who may be engaged in this service; for besides being extremely interesting on account of the many dashing and daring attacks on ships made by both Federals and Confederates with the spar torpedo, as well as the numerous brilliant efforts made with more or less success by the fleets of the former, to break through the submarine defences of the latter, it also affords a highly instructive lesson on the subject of *extempore* mine defence, when circumstances necessitate the adoption of such means for the protection of a harbour. In considering this portion of torpedo history, there are two points which should be carefully borne in mind by the student, first the crude nature of the apparatus employed, and the inexperience of the officers and men connected with this work of submarine defence, and secondly the composition of the fleets on the side of the attack.

In the first case, of the mines laid down by the Confederates, ninety per cent. were mechanical self-acting ones, carrying a small charge of gunpowder, and provided with a means of ignition somewhat slow and uncertain in its action: a few controlled mines were used, but the electrical apparatus was naturally faulty, electricity in its application to submarine mines being then little understood. It is not therefore very surprising that in one instance only is it recorded that a mine of this class was successfully exploded at the right moment, when however it most completely effected its purpose by blowing out of the water the unfortunate Federal ship (*Commodore Jones*); a result due partly to the use of electrical means for igniting the charge by which it was exploded in real contact with the bottom of the vessel, but more particularly on account of the exceptionally large (1000 lb.) charge of gunpowder with which it was loaded.

The absence of any proper system of *controlled* submarine mines on the side of the Confederates very materially assisted the Federal naval commanders in their numerous attempts at forcing the passages of harbours and rivers of the enemy, for it was thereby necessary for the Southerners to leave a broad navigable channel totally unprotected by mines, in these places, for the passage in and out of their own war ships, blockade runners, and other friendly vessels, as the use of the self-acting mine for this purpose would have closed these channels equally to friend as to foe, and they dared not plant them with the *then* unreliable controlled mine, even had they possessed a sufficient number for this service.

In the second case, as the Federal navy, consisting at the close of the war of some four hundred vessels, was principally composed of lightly-built wooden ships, turned out as fast as they were needed, the Federal Admirals were enabled to evade all considerations as to the loss of any number of vessels in their endeavours to capture a harbour or to force the passage of a river in the hands of the Southerners, provided only that the effort was attended with success, or even partial success; thus the loss of some ships by torpedoes and submarine mines was to the Federal navy of, comparatively, little importance.

The modern Navy, though ship by ship immensely more powerful than any of its predecessors, was then and is now in point of numbers lamentably weaker; and in a serious naval war it would become very dangerously crippled by the loss of a very small portion of its ships, a consideration which must have a very important influence on the conduct of naval operations of the future, whether from a torpedo or other point of view, for an immense responsibility would thus be thrown on the naval commander of an attacking force in the event of his losing any of his ships, and oblige him to consider the safety of his fleet before the success of the enterprise. This consideration must always seriously interfere with the execution of those dashing tactics which, twenty-six years ago, alone enabled the Federal fleets to penetrate and capture Confederate harbours and rivers, sown, as they were known to be, with the deadly self-acting mines, at the same time increasing the effectiveness of the submarine mine for defence by enhancing its *moral* power.

Want of Development of the Mine and Torpedo in succeeding Wars.—The value of the spar torpedo for attack, and of the submarine mine for defence, though both were full of the imperfections common to new inventions, more especially when constructed of improvised material, was so clearly and practically demonstrated during the American Civil War that the student of torpedo history would be led to expect a constantly increasing development of this mode of warfare in each succeeding naval war; but, astounding as the fact may appear, neither the submarine mine, nor the torpedo, has played a very conspicuous part in either of those which have occurred since that great struggle, which include that between Paraguay and Brazil (1864–8), Austria and Italy (1866), France and Germany (1870–1), Russia and Turkey (1877–8), Peru and Chili (1878–9), France and China (1884).

Submarine warfare has been practised to a certain extent in each of these instances, but with the exception of adducing further testimony of the vast power of the submarine mine and the torpedo in paralysing the advantages, which, in each case, one of the opposing sides held over the other in the matter of naval superiority, by the mere dread of their supposed latent capabilities for destruction, and the suddenness and invisibility of their action, a most lamentable failure, totally incomprehensible, was exhibited by each side in these wars to take advantage of the power of the torpedo for attack, and of the mine for defence, though the Paraguayans, Turks, Peruvians, and Chinese, had splendid opportunities for utilising these implements in their most effective manner.

Effect of the Moral Power of the Submarine Mine.—Had it not been for the moral power of the mine, the Brazilians would have more rapidly brought to a close their war with the Paraguayans. But for this silent force Venice, Pola, and other Austrian ports, would not have been left unmolested by the ships of Italy, nor would the splendid navy of France have proved so utterly useless to the French in their great need in 1870; and, but for this dread of the torpedo and the mine the incapacity of the Turks to make full use of their immense superiority on the Danube and in the Black Sea in 1877 would not have to be recorded.

Failure to utilize the Torpedo by the Turks, Chinese, and Russians.—Again, had it not been for the apathetic indifference displayed by the Turks in 1877, and the Chinese in 1884, the crossing of the Danube by the Russians would have been an almost impossible operation, and the capture of Foochow by the French fleet in the daring but decidedly rash manner in which it was executed could never have been so easily effected. On the other hand, a practical knowledge of the use of the Whitehead, Harvey, and spar torpedo, and a properly organised method of operating the same, with a slight soupçon of dash thrown in on the part of the Russian torpedoists, must have secured the destruction of the major portion of the ships of the Ottoman navy in their Black Sea ports, and on the Danube; for if ever ships invited destruction by such weapons, it was in the last Russo-Turkish war.

It is seen that, for some reason or other, quite unaccountable in any logical manner, the important lessons taught the world by the Southerners in the art of torpedo warfare, in their vain but splendid struggle for independence in 1861, were not accepted, or taken to heart by those Powers who have been engaged in war since that time, although, inconsistent as it may appear, the power of the torpedo and of the submarine mine was acknowledged by these same Powers, one and all, as demonstrated by the terror occasioned by the mere supposition that such were, or were likely to be, used by their opponents.

Cause of failure of the Submarine Mine and Torpedo to fulfil expectations.—The failure of the torpedo and the mine to fulfil the great expectations formed of them, from the success attending their use by the Confederates, in the wars that have occurred since then, especially in the case of the Franco-German war of 1870, and the Russo-Turkish war of 1877, cannot be attributed for one moment to any inefficiency in the implements themselves, but to the want of a proper system, the inexperience of the operators, and more particularly to the reprehensible measure of procrastination adopted by these governments in the matter of organising, and providing the requisite material for a complete system of submarine offence and defence, until events should occur which would oblige them to have recourse to war to assert or defend their rights; but however anxious they may then have been to obtain all they required in the way of torpedoes and mines, their position altogether precluded them from securing the needful material, and even if the proper kind and amount had been available, there would still have been lacking that most essential element of success in submarine warfare, viz. experienced officers and men for the manipulation.

Need of Preparation.—The absolute necessity of preparing, in a time of peace, a carefully devised plan of submarine defence, and to provide all the necessary material of the most approved modern pattern, and also a fair proportion of torpedo material for offensive operations, cannot therefore be too strongly urged on every naval power; at the same time, it is equally incumbent on them to insist on their respective torpedo corps being regularly and carefully trained in all the details and practice of submarine warfare; the practice being assimilated, as far as possible, to what is likely to occur in actual war.

Finality has most certainly not yet been arrived at in the matter of torpedoes, and of a system of submarine mine defence, more especially in the case of controlled locomotive torpedoes; but a sufficient degree of perfection has been realised to admit, at the present time, of the preparation of a definite and essentially practical plan of harbour defence by these means.

The safeguarding of the honour, and the integrity of every naval power, will depend in the future as much on the measure of perfectness of her submarine as on her naval and military systems.

Present Condition of the Defence of Harbours by Mines.—The present condition of the means of defending harbours by submarine mines presents no important development of the material belonging to this branch of submarine warfare during the last seven years, and the reason for this apparent stagnation can only be attributed to two causes; in the first place, there is the ever-present fact that torpedoists in general have more particularly directed their energies to increasing the efficiency of the fish torpedo, or of inventing, or improving new forms of such like implements of submarine offence, which possess the charm of exciting the wonder and admiration of the torpedo public in a degree not attainable by any improvement or invention, however valuable, in connection with the torpedo's more placid and impassive brethren, submarine mines.

It is self-evident that the improvement of the Whitehead, and the devising of a controlled locomotive torpedo for harbour defence, and for ship use, is a highly commendable work, and deserves every effort on the part of torpedoists generally; but at the same time this service should not be permitted to monopolise their whole attention, to the detriment of the submarine mine, which is, after all, the chief factor of harbour defence.

The question of Secrecy in regard to the details of Submarine Defence.—The other cause alluded to is the unfortunate belief engendered in the minds of most officers of torpedo corps, that absolute secrecy in all that appertains to the constructive details of a system of submarine mine defence, is an essential of its successful application in actual war, and that therefore all improvements in this direction must emanate solely from the corps, and that outside work of this nature must on no account be encouraged.

Necessity for Steady Development of the system of Submarine Defence.—It cannot however, be too strongly impressed on those who are responsible to their country for the perfectness of the defence (submarine) of her coasts, that neither of these causes ought for one moment to be permitted to impede the steady development of the various details of submarine defence, for it is unquestionable that the mine will prove a far greater power for the purpose of defence, than the torpedo for *purely* offensive operations.

Secrecy necessary in planning the Defence of a Harbour by Mines.—Secrecy in regard to the planning of the submarine defence, for each particular harbour, is a desideratum to be secured in the most absolute manner, but secrecy in construction is to be deprecated because by its adoption it precludes the employment of the talent of those private individuals who are devoted to the work of improving the material connected with submarine mine defence, whilst past experience teaches the impossibility of maintaining the requisite degree of secrecy in so far as the torpedoists of other countries are concerned, if only the secret matter, which a torpedo corps desires to be kept from their knowledge, is considered worth the price for which such information is always to be obtained.

The question of "Esprit de Corps."—There is of course a certain amount of *esprit de corps* to be taken into account in considering this matter, *i.e.* the *kudos* claimed by the members of a torpedo corps in the event of their being able to devise improvements in submarine war material, without availing themselves of outside talent, but who is there to judge as to the practical importance of such work, save the members of the corps? Again, as any improvement or invention emanating from private individuals in connection with torpedoes and mines must be submitted to the torpedo corps of any country where it is desired to introduce it, the members alone are able to decide as to the originality of any improvement or invention claimed by the torpedo corps.

The desire of every Government.—It must surely be the sole desire of every Government to procure the most perfect material available for the protection of their coasts with a system of submarine mines, and whether it be the invention of members of their torpedo corps, or of outsiders (their own countrymen or foreigners), ought not to interfere with its adoption. Of course it must be expected that a first preference will be accorded to that which emanates from the torpedo corps, but then a careful and exhaustive comparative test ought to be applied to establish its superior or equivalent value to similar material which may, at the same time, have been produced by outsiders.

The question of Private Inventions.—Many inventions and improvements in connection with submarine warfare, the product of the labours and ingenuity of private individuals, are submitted to the authorities, which, though possessing the germs of success, may not be perfect in its every detail, and thus fail in their first practical official experiment, and are rejected by the torpedo commission, when, if taken in hand by them with the means at their disposal for rendering a theoretically perfect detail into a practical shape, these, or at least some of them, might be turned to valuable account.

The want of a good Self-acting Mine.—Proceeding now to a more detailed consideration of the development of submarine mine defence since 1879, it has first to be recorded that a self-acting mine in which is combined the capabilities of being moored, and picked up at any time with perfect safety, and of acting with absolute certainty when brought into contact with a hostile ship, remains still a desideratum, though there are several different kinds of mines of this nature now in use possessing in a more or less high degree the feature of safety in mooring and certainty of action, but which when once moored and rendered active, are somewhat dangerous to remove, whether by friend or foe; but surely if adequate inducement be offered to private manufacturers of torpedo material, and a strenuous effort be made by torpedo corps, this want need not, and should not, be permitted any longer to exist, for there cannot be any insurmountable difficulties peculiar to this form of mine to prevent the consummation of its requirements.

The question of Mooring Mines.—In the matter of mooring, having special reference to the self-acting and smaller controlled mines, there has been devised a very ingenious method of automatically anchoring them at any desired distance below the surface of the water in places of unknown depth, which, in a practical form, must decidedly prove most useful under certain special conditions of naval warfare.

There is also another very ingenious method now being tried of holding buoyant contact mines down to their moorings by means of explosive links, so as to prevent the mines from being struck (a prevalent cause of damage) by the passage of ships in and out of a harbour during a time of peace. By firing the charge in these links the mines become free to ascend to their proper distance from the surface whenever a need for their action is called for, as in a time of war: for mooring the self-acting mine a somewhat similar plan might possibly be adopted with advantage, the explosive link in this case taking the place of the one which attaches the mine wire cable to its anchor, so that destroying the link frees the mine, which by its buoyancy will rise to, and become exposed on, the surface, and in that position be more easily and safely picked up, when its removal for any purpose is necessary.

Improvements effected in regard to Mine Instruments.—Some useful improvements have been effected in circuit closers, and in shutter, testing, and firing apparatus in the direction of enhancing their certainty of action, simplicity of construction and manipulation, and in the case of the former, their immunity from action in the presence of the explosions of neighbouring or counter mines.

The want of Development of a Single Main System of Submarine Defence.—The system of testing and firing a number of mines separately through the medium of a single cored main cable in place of a multiple one, by which certain important advantages are obtained, has made but little progress in securing the favour of official torpedoists since its introduction some seven years since, though by the addition of a second core in the main cable, and other alterations, this system has been brought into a more practical shape; the advantages of this method of mine defence are worth closer attention by the members of torpedo corps than has so far been accorded it.

The Progress of Torpedoes considered.—The Submarine Boat.—The advance that has been effected in all that appertains to torpedoes and their use, has been on the whole satisfactory, though it is mainly confined to the surface torpedo boat, and the fish torpedo. At the same time, by reason of the very successful results attained with one of the latest types of submarine torpedo boats, this class of fighting vessel must also be considered a very possible factor of naval warfare in the immediate future. In England, however, a belief still prevails in the

Navy decidedly antagonistic to the employment of such craft, a feeling that has arisen partly from the uncanny nature of their *modus operandi* in attack, but principally because of the numerous disasters that have *previously* attended their use both in war and peace time; this feeling, however, will most decidedly have to be given up by English torpedoists now that the submarine boat has apparently become accepted by other powers (Turkey, Russia, Greece) as a component part of their naval equipment.

It may now be accepted as a fact that a submarine boat can be constructed which shall possess a fairly high speed while running on the surface, and which shall be navigated with perfect safety under the water at considerable depths, and for some hours. But it has still to be demonstrated, in a practical manner, that such craft are capable of operating in a satisfactory manner as *torpedo* boats, a result doubtless quite feasible.

The Fish Torpedo.—Dealing next with torpedoes, it is to be noticed that torpedoists, especially in England and Germany, have devoted their attention chiefly to the improvement in speed and accuracy of the Whitehead and Schwartzkopff fish torpedoes, and, though a very fair degree of success has attended their efforts in regard to the former quality, yet the actual effective range of these weapons has been but slightly increased, though the certainty of hitting a ship with them at some three to four hundred yards' range under ordinarily favourable circumstances is pretty well assured with the latest types. The Schwartzkopff fish torpedo, which has been lately introduced, is in most respects identical with the Whitehead, with the exception that the material used for its hull is some species of phosphor bronze in the place of steel.

The Schwartzkopff system of construction is often compared unfavourably with the Whitehead method in the matter of speed, but the reason why these German Fish torpedoes are constructed for a less high rate of speed than those turned out at Fiume and Woolwich is solely due to the insistance of the Germans that their fish torpedoes should possess a *uniform* speed (some 22 knots), thus avoiding the necessity of a special set of divergent tables to suit each particular torpedo, and this is a point deserving of careful attention.

The "Resistance" Experiments.—The results of the recent experiments with the Whitehead torpedo against the *Resistance* ironclad conducted by the English naval authorities, would point to the fact that the deadly nature of this weapon's attack has been very greatly overrated, for the results so far obtained clearly demonstrate that a ship's torpedo net is a very capable means of protection to the vessel, by causing the explosion of the Whitehead at a distance which nullifies its destructive effect, in so far as the ship is concerned; while even in the case of a Whitehead, with a charge of 90 lbs. of gun-cotton, arranged in position so as to be fired in actual *contact* with the submerged portion of the hull of the *Resistance*, the damage caused was far less than what had been confidently expected. If the vessel had been under steam at the time of the explosion, and it were possible for such a torpedo to attain the position accorded it in this particular experiment, then probably a greater amount of damage would have been caused.

The particular experiment under notice in which a Whitehead was fired in contact with the *Resistance*, looking to the peculiar conditions under which this experiment was made, cannot be claimed as proving anything as to the true capabilities of the *Whitehead*, for it was merely an additional proof of the effect capable of being produced on a ship by a certain charge of gun-cotton exploded in contact therewith, as any other kind of *case* would have sufficed equally as well for the purposes of this demonstration.

Controlled Locomotive Torpedoes.—In England an attempt has been made to obtain a suitable locomotive controllable torpedo, and for the last five years numerous experiments have been made under the superintendence of the Royal Engineer torpedo corps with a weapon of this kind, which have lately been brought to a comparatively successful conclusion; but a controlled torpedo which requires, as this one does, for its propulsion more or less extensive machinery at the point from which it is to be manœuvred, can hardly be looked upon as the *ne plus ultra* of such implements, for it is thereby rendered unsuitable for harbour defence or other purposes, as its scope of action is much curtailed. Further, though this particular invention is certainly most ingenious, in so far as its system of propulsion is concerned, yet the main feature of success claimed for it, viz. its submergence, is in no wise a speciality of this invention, but is merely an adaptation of the well-known Whitehead system of submergence, and therefore open to adoption by any other inventor of similar torpedoes.

The reason why this particular system of locomotive torpedo was originally taken up by the Royal Engineer torpedoists without pitting it against other similar weapons, was that they saw the possibility of so improving and altering it, that they might fairly claim it, in its new form, as a veritable child of their own, a matter overbearing apparently any question as to whether it was the most suitable form or not; while if only they could succeed in keeping the improved details of construction a complete secret, then England would possess a locomotive controlled torpedo whose mode of action would be unknown to all the world besides. As, however, this invention, in its original form, has been patented, any other government has an equal chance of constructing it in an improved form; while it cannot be doubted that any foreign torpedoists anxious to obtain particulars as to this Chatham implement will be easily able to secure all the information necessary.

The Spar Torpedo.—The spar or outrigger torpedo, though it has often proved a very effective weapon, and recently in the hands of the French was the means of sinking some Chinese vessels of war in 1884, yet is held of comparatively little account by torpedoists generally, and so has received hardly any attention towards developing it of late years; but as this torpedo has scored all the successes hitherto obtained with movable torpedoes, with the exception of a rather mythical achievement with a Whitehead in the Russo-Turkish war, 1877, and because it possesses the admirable quality of being absolutely under the immediate control of the operator, up to the moment of its explosion in contact with the ship, it is to be regretted that it has apparently been discarded for the more or less erratic Whitehead fish torpedo.

The Towing and the Drifting Torpedo.—The *towing* torpedo may be considered as a thing of the past, and its history most decidedly warrants its being put on one side; while the *drifting* torpedo must await the occurrence of a war, where its peculiar requirements will be afforded a chance of proving its many useful qualities, when the attention it will then claim will be the means of creating improved forms of the present somewhat antiquated types.

The Development of the Surface Torpedo Boat.—In the matter of the surface torpedo boat a very decided development will be apparent as compared with its prototype of 1873, more especially as regards the increased size of these craft: in fact, so rapid has been this increase in each successive type that the largest boats now being constructed have almost, if not altogether, passed the line of demarcation between boat and small ship.

The insatiate desire for high speed at any cost has been the immediate cause of the very rapid growth of the torpedo boat, but though high speed is most certainly a desideratum for such craft, yet it is indisputably an error of judgment to look only to the capability of the later type of torpedo boat to beat its predecessor when running on its builder's trial trip by a mere fraction of, or even by a whole knot; for it is a fact, only too familiar to naval men, that rarely indeed does the specially high speed ship or torpedo boat on *actual service*, attain the same high rate of speed that she undoubtedly achieved in the hands of her builder on the initial official trial. It is sometimes urged in respect of this statement that the highest possible speed ought to be attained at this particular trial, so that the speed on actual service, under the same conditions of wind and weather, though more or less reduced, may yet be a fairly high one; but a phenomenal high rate of speed on the official (builder's) trial can only be brought about by some sacrifice of the boat's general efficiency when tested under ordinary conditions at sea, and fully loaded and equipped. It would seem therefore to be more practical and sensible to sacrifice a certain amount of this hypothetical speed, and in lieu thereof provide a more seaworthy and roomy craft capable of maintaining for some hours a speed of say 21 knots at sea under ordinary conditions of wind and weather, when handled by naval engineer officers and stokers, and with the ordinary kind of service coal: in other words, reduce the length, and increase the beam of the boat, and at the same time increase the strength of the engines and the coal supply.

In considering this question of the size and speed of the sea-going torpedo boat, it has been assumed to carry as its torpedo equipment the Whitehead, or Schwartzkopff fish-torpedo, and therefore its destructive effectiveness is that of these weapons; but the result of the *Resistance* experiments with this weapon has proved that its power of dealing a death-blow to a first-class ironclad is not such as it had formerly been credited with, and thus the fish-torpedo has lost, to some extent, its moral power, thereby tending to increase the steadiness of the fire of the defence, or, in other words, adding to the dangers, already great enough, attending an attack by torpedo boats, from the fire of the ship's machine and other guns, while the larger the boat, the better target it offers; but when the naval authorities of all countries shall awake out of their lethargy in regard to the employment of the controlled locomotive torpedo with torpedo boats, then, as the range of attack will thereby be immensely increased, the great size of the present sea-going boat need not be so seriously entertained as a disadvantage.

The Introduction of the "Hunter."—The great number of torpedo boats manufactured of late years for the different navies of the world, coupled with the vast power of offence accredited to them, has forced the introduction of what are variously termed torpedo-boat catchers, destroyers, or hunters, and the principles on which the few vessels of this special type already built have been designed are superiority in the matter of speed, size, strength, seaworthiness, coal endurance, and manœuvring powers over the sea-going torpedo-boat, and by constructing "hunters" of from two hundred to three hundred tons, all the features of superiority enumerated above, with the exception of speed, have been secured; though not quite so fast on the measured mile, these "hunters" will probably more than hold their own with the fastest torpedo-boats at sea on real service. In the matter of the armament of these "hunters" considerable difference of opinion exists as to whether they should, or should not, be provided with a torpedo equipment in addition to a powerful rapid-firing machine-gun armament: the opponents of the former view very reasonably argue that these "hunters" would then very likely be employed as *torpedo*-boats, and thus be seduced away from executing the peculiar and important work for which they have been especially designed.

The Dynamite Gun.—The dynamite gun, *i.e.* a gun not fired by dynamite, but which discharges shells, or torpedoes, as the inventor terms these projectiles, loaded with that explosive compound, must be mentioned; for if this weapon ever becomes adopted as a component part of naval armaments, it will most assuredly very seriously affect the present condition of naval warfare; especially so will this be the case in respect of the bombardment of forts by ships. As yet, however, this new implement of war has not been received with any great favour by the naval powers generally, owing to a lingering suspicion that a good deal of risk must ever attend the discharge from a gun of shells loaded with an explosive of so highly excitable a nature as dynamite, for if a shell by any accident exploded prematurely in the gun, it would cause most terrible havoc. The experiments in America with a pneumatic dynamite gun so far carried out have however resulted satisfactorily, and a boat is now building for the United States Navy carrying three of these guns.

The Submarine Gun.—Submarine guns, i.e. guns which are arranged to discharge their projectiles under water, are also considered as a possible naval weapon of the future, but the trials recently conducted in England, with an invention of this kind, have somewhat failed in establishing the practical effectiveness claimed for it.

The Electric Arc Light.—The electric (arc) light, which is a very necessary element of torpedo warfare, together with its accessories, as the dynamo machine for generating the electric current, the steam engine which operates the dynamo, the switches, measuring instruments, &c., have been very much improved during the last seven years, more particularly in respect to the greater efficiency of the generating machine; but there still exists some difference of opinion as to the best position in a ship in which to place the search-lights; for instance, whether aloft in the tops, or below on the bulwarks, bridges, &c., also as to the proper number of lights each class of ship should be provided with, and as to whether the defending guard boats and attacking torpedo boats should be supplied with one of these lights. Then there also remains still to be settled the most practical method of utilizing the electric light for attack and defence, and the various torpedo operations which have within the last year been conducted in England and abroad seem to have failed in solving this vexed question.

The question of the Protection of Ships against the Attack of Torpedoes.—A most important problem in connection with naval warfare, viz., the protection of ships against the attack of torpedo boats, has apparently received but scant attention since 1879, for, with the exception of some improvements effected in the construction and fitting of ship torpedo nets, no development whatever has taken place in this direction, and it is most probable that since the success of the net in the Whitehead experiments against the *Resistance*, this matter will remain *in statu quo*. In considering the case of a ship *at anchor*, as she can then resort to the use of the net protection without impairing

·r efficiency, she may now be thought to be fairly safe against the tack of the present fish torpedo; but the case of a ship *at sea* is very fferent, in so much as the use of nets, as at present fitted, seriously duces her speed, and consequently her manœuvring powers, so that nder such circumstances a ship attacked by torpedo boats would have › depend entirely for her safety on her speed, turning powers, and ght gun equipment.

This problem of ship torpedo defence at sea is unquestionably a nost difficult one, for the reason that the provision of adequate pro-ection, without at the same time in any way detracting from the steaming and manœuvring power of a ship, is apparently only feasible by imparting to the vessel itself the feature of unsinkableness, and though many methods have been suggested with a view to secure to a ship of war this needful quality, yet so far none have met with the approval of practical naval architects in general. It hardly seems necessary to point out the extreme importance of this question, but it cannot be too strongly urged on our naval anthorities to use their very best endeavours to solve this problem. The great strides that have been made of late, and are still being made, towards the development of the rapid firing and the machine gun, most certainly affords to a fast and rapidly turned ship at sea a very valuable power of defence against the torpedo boat; but valuable though these means may be, yet they would count but as nought in comparison to a ship rendered, by a peculiar form of construction, impervious to the explosion of one or more Whiteheads in contact with her hull.

The need of a great Naval War to settle Questions.—The occurrence of a great naval war between two Powers, each properly provided with the most perfect system of submarine offence and defence attainable, is necessary before any definite and satisfactory settlement can be arrived at of all the numerous vexed questions which now exist as to the most effective method of application of the various component parts which together make up the whole art of torpedo warfare. At this time the only point accepted as a fact by the majority of naval and military men, is the vast "moral power" of the submarine mine, and the torpedo, and even of the dummy mine. They are the unknown quantity in warfare, and must materially affect the imagination of any commander who knows or believes them to be possessed by the opposing force.

SECTION I.

THE DEFENCE OF HARBOURS

BY

SUBMARINE MINES.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER I.

GENERAL REMARKS.

THIS section will be devoted to a complete consideration of the theory and practice of the various means extant for the defence of harbours, rivers, &c., by means of submarine mines.

Definitions.—It is advisable here to define the meaning of the nomenclature which more particularly belongs to submarine mining in all its various branches.

Submarine Defence.—The defence of harbours, rivers, &c., by submarine mines.

Submarine Mines.—Charges of explosive contained in cases moored beneath the surface of the water—often termed "Sea" Mines.

Mines.—This term will be used to signify all kinds of submarine mines, for the purpose of avoiding the constant repetition of the expression "submarine," which is only necessary when distinguishing between those mines used on shore, and at sea.

Self-acting Mines.—Mines which are fired automatically, and which cease to be under control from the moment of their becoming active. These may be either "mechanical," or "electrical."

Self-mooring Mines.—Mines which are arranged to automatically moor themselves at any particular depth for which they are set.

Controlled Mines.—Mines, ground or buoyant, whose firing is absolutely under control at all times.

Counter-Mines.—Mines which are used by an enemy to destroy the mines of the defence, or to render them useless, which is effected by exploding them (counter-mines) in the neighbourhood of the mines of the defence.

Counter-mining.—The operation of laying counter-mines.

A Mine Field.—The whole space covered by the mines of a system of submarine mine defence.

Group of Mines.—Two or more mines arranged to be fired simultaneously on the same firing circuit.

Dummy Mines.—Mine cases laid down without explosive, for the purpose of misleading an enemy attempting, by sweeping, to clear a passage through a mine field.

Mooring.—The means adopted to anchor and retain buoyant mines in their proper position.

Tidal Moorings.—Special devices for maintaining a buoyant mine at a fixed distance below the surface of the water in harbours, and rivers where a considerable rise and fall of tide is experienced.

Observation Firing.—The method of firing a mine, or group of mines, at the moment when, by cross-bearings or other means, the ship to be destroyed is observed to be actually over the said mine, or group of mines.

Firing by Contact.—The method of firing a mine only on actual contact with a ship.

Firing at Will.—The method of firing a mine at any moment at the will of the operator at the mine station.

Mine Stations.—Positions on shore from which the controlled mines are tested and fired.

Observation Stations.—Positions on shore from which the relative position of a ship passing over the mine field and a mine or group of mines is observed, when the system of observation firing is used.

Circuit Closers.—The instrument placed either inside a mine itself, or in a separate buoyant case attached to a mine, whereby the firing (electrical) circuit can be closed by contact, or at will.

Junction Box.—A metal box in which the joints forming the connection between the main and mine cable is placed.

Disconnector.—A metal box in which a fuze (cut out) connected between the main, and the mine cable is placed to insulate and cut that particular mine out of the circuit of the other mines (which are also connected up to the same main cable) when it has been exploded.

Multiple Cable.—An electrical cable containing a number of insulated copper wires.

Sea Instrument.—An electrical instrument placed in the junction box of a single or double main cable system, whereby a single or double cored cable is able to perform all the functions of a multiple cable for any number of mines.

Shore Instrument.—The electrical instrument placed in the mine station on shore by which the testing, signalling, and "at will" firing of a system of mines is manipulated, *i.e.* by which they are controlled.

Mechanical Primer.—Apparatus for firing a mine mechanically on contact.

Safety Plug.—A plug, usually formed of a material readily dissolved by water, and which is used to render a self-acting mine safe in handling, while laying it in position.

Fuze.—The means whereby a charge of explosive is fired.

Mechanical Fuze.—A fuze arranged to ignite a charge by mechanical means, *i.e.* by percussion.

Chemical Fuze.—A fuze arranged to ignite a charge by chemical means.

Electrical Fuze.—A fuze arranged to ignite a charge by means of the electric current.

Firing Key.—An electrical instrument for enabling the firing circuit to be closed at any moment by the hand of the operator.

Operator.—By an operator is meant the officer or person who directs the testing, or firing of controlled mines, or who is in charge of the observation firing instruments.

Classification of Submarine Mines.—Submarine mines are divided into two distinct classes, each one of which embraces a variety of different kinds.

These two main divisions are:—

A. Self-acting Mines.
B. Controlled Mines.

This nomenclature has been adopted as more clearly expressing the difference that exists between these two classes of mines, than the terms *mechanical* and *electrical* for "self-acting" and "controlled" respectively, which have heretofore been commonly employed to distinguish between those mines fired by automatic means alone, and therefore *uncontrolled*, and those fired either automatically on contact, or at will, but which are always perfectly under *control*, because the use of electricity as the firing agent is now common to both the self-acting, and the controlled mine.

A. *Self-acting Mines.*

This class of submarine mine includes all those the firing of which is absolutely automatic, and altogether removed from any control after they have once been moored and rendered active by the removal, automatically or otherwise, of a safety pin, or of a safety plug; mines of this class can thus only be fired by contact.

There are two distinct subdivisions of self-acting mines.

a. Mechanical.
b. Electrical.

Self-acting Mechanical Mines.—This class of self-acting mines includes all those that are provided with mechanical ignition of some kind or another; for instance, a heavy weight on the outside of the mine attached by a line to a friction tube, and which (the weight) is detached by contact between the mine and ship, and which in falling fires the tube: or a weight fixed inside the mine falling, when detached, on to a percussion cap or fuze: or again, a hammer inside the mine fixed at full cock and released by the oscillation of a weighted spindle on the contact of a ship with the mine: or percussion, or chemical fuzes protruding on the outside of the mine, which are set in action by the blow of a passing vessel.

Self-acting Electrical Mines.—This description of self-acting mine differs from the foregoing only in that the ignition of the charge is effected by *electrical* in the place of *mechanical* means.

Various devices for the firing of self-acting electrical mines are in vogue, among which may be mentioned the following more notable ones: a small battery without its electrolyte is placed inside the mine with the fuze in circuit; then to generate the current by which the fuze is fired the electrolyte alone is needed, and this is contained in a closed glass tube fixed to the outside of the mine case and immediately in connection with the aforesaid battery, the glass tube being again enclosed in a lead casing, the bending of which, due to contact between the mine and a passing ship, causes the glass tube to break, and the electrolyte to thereby flow into the battery beneath, completing the firing circuit; another device is to provide the mine with a circuit closer of some kind or other which is only brought into action to close the firing circuit by the shock of a ship colliding with the mine; the battery in this case (a complete one) may be either placed in the mine itself, or in the mine's mushroom anchor, or it may be sunk at some distance from the mine; in the former method the circuit closer is prevented from acting, by means of a safety plug, until a certain safe period of time has elapsed from the moment of the mine being moored in position.

Advantages of Self-acting Mines.—Self-acting mines possess the following advantages :—

1. They are comparatively cheaply and readily constructed.
2. They can be kept in store ready for use at a moment's notice.
3. They do not require specially trained men for their manipulation.
4. Extempore ones can be readily devised and constructed.

The advantages here enumerated, more especially the two first, render the self-acting mine a most valuable means of defence in the following positions :—

1. In combination with booms, or other obstructions placed in defence of narrow channels, &c., which are intended to be completely blocked to friend and foe.
2. In shallow waters on the flanks of a system of controlled mines.
3. In blocking unfrequented bays, channels, &c., that might otherwise be left entirely unprotected.

Disadvantages of Self-acting Mines.—The principal objections to the employment of this class of mine, except under special conditions of time and place, are as follows :—

1. That self-acting mines are all more or less dangerous to place in position.
2. That the condition of the igniting apparatus, mechanical or electrical, cannot be tested when once the mine is rendered active.
3. That they are as dangerous to friend as to foe when once the safety plug or pin has been removed from them.
4. That an exploded self-acting mine, or one known to be damaged, cannot be replaced.

These disadvantages constitute a very serious objection to the use of the *self-acting* mine, but nevertheless for the particular purpose of blocking unfrequented bays, river mouths, channels, &c., where it may not be deemed necessary to resort to the more elaborate and costly system of *controlled* mines, this class of mine will be found of some considerable service; while in so far as these mines are self-acting in their action, they cannot be rendered useless or harmless by the mere capture of a mine station, as is possible in the case of a system of defence by controlled mines, in which case a mine station falling into the hands of the enemy may be the means of rendering abortive a considerable portion of the submarine mine defence; but in the case of an enemy requiring to utilise a place in which a number of these self-acting mines were known to have been laid, each one of them would have to be separately picked up, or if counter-mining was resorted to for the purpose of clearing the place, the ground would have to be most carefully swept before it could be considered safe for their ships to traverse; and as this is a work of considerable labour and some danger, a serious delay would at the least be occasioned to an enemy desirous of utilising a place planted, or supposed to be planted, with a number of these self-acting mines.

Mooring Self-acting Mines.—It is advisable here to point out how exceedingly important it is to pay the most careful attention to the mooring of self-acting mines, because in the event of one such mine breaking adrift it would be impossible, even for those who laid it down, to know with any degree of certainty its whereabouts, and this vagrant mine would thus be drifted about at the mercy of the tide or current, ready on the slightest provocation, by friendly or hostile vessels, to deal its death blow.

B. *Controlled Submarine Mines.*

This class of mine includes all those that are provided with apparatus (electrical) such that renders them at all times absolutely under control, *i.e.* they may be set to be exploded automatically on contact with a ship, or they may be arranged to explode only when so desired by the operator at the mine station, whether in contact with a ship or not; or again, they may be exploded automatically at the moment when by some method of observation a ship is known to be actually over one of them; while, no matter what system of firing be in use, they can be rendered at any moment perfectly harmless by the interruption of the firing circuit, effected either by the removal of a plug, or by the switching over of a key, or by detaching a wire from the firing battery; lastly, the condition of controlled mines can be ascertained at all times by a pre-arranged system of testing.

This class of mine was heretofore known as "electrical" mines, but though this term is strictly correct, yet, as electricity is now also applied to the firing of the self-acting mine, the present term "controlled" more clearly designates the wide and important difference that exists between these two classes of submarine mines.

Controlled mines consist of two distinct classes:

1. Ground Mines.	*a.* Observation. *b.* Combination Contact.
2. Buoyant Mines.	*a.* Electro-Contact. *b.* Combination.

Ground Mines.—This type of controlled mine, as its name implies, is always laid on the bed of the harbour, river, &c., when it is used, where it forms its own anchor.

The ground mine is usually employed as a purely *observation* mine, *i.e.* is fired by some method of observation, when it becomes the very simplest form of submarine mine, and is then intended for planting in narrow and shallow waters; the ground mine may however be connected with a circuit closer carried in a separate *buoyant* case, in which case it is termed a combination contact ground mine, a method resorted to only when a very heavy charge of explosive is required, and where the depth of water is comparatively shallow.

The advantages and disadvantages of Ground Mines.—This type of *controlled* mine possesses the following advantages:—

1. It permits of the use of a heavy charge of explosive without corresponding difficulties in mooring and in fixing its position.

2. The observation ground mine is not liable to be damaged by the frequent passing in and out of ships, as it is laid on the bed of the harbour, &c.

The one serious defect of an observation ground mine when used *without* a circuit closer, is that it has then perforce to be fired by some method of cross-bearings, or observation, and therefore is subject to all the disadvantages common to this system of firing, as explained at page 31, and which very seriously militates against its effectiveness as a means of harbour defence; notwithstanding this it will, however, be found necessary in certain places to resort to the use of these observation ground mines.

Controlled Buoyant Mines.—The buoyant mine, as its name implies, is intended to be floated at a certain fixed distance below the surface of the water, and consequently has to be provided with a certain amount of reserve buoyancy, which is restrained from floating the mine to the surface by means of a wire rope, or chain cable connecting the mine to a heavy anchor.

This type of mine is essentially a contact fired one, and is then provided with a circuit closer of some form or other, which may be placed either in the case containing the charge, *i.e.* in the mine itself, when the mine is termed an *electro-contact* one, or the circuit closer may be placed in a separate buoyant case and connected electrically to the fuze in the mine, the buoyant case carrying the circuit closer being anchored to the mine case, when it is termed a *combination* mine.

A buoyant mine may of course be utilised as a purely observation one, in which case no circuit closer is required, but this method of using a buoyant mine is most unadvisable, and unpractical, for except for the sake of cheapness in the saving of the cost of the circuit closer, there is no reason whatever why a buoyant mine arranged to be fired by observation should be denied all the advantages accruing from contact firing as well.

Advantages and disadvantages of Controlled Buoyant Mines.—It will be necessary to consider this question in relation first to the electro-contact, and then to the combination buoyant mine, and compare them with the ground mine, and one with another.

The principle of the electro-contact mine is that it is exploded in actual contact with the submerged hull of a ship striking it, and therefore it needs but a comparatively small charge to secure the maximum effect of an attack of this nature, and thus as regards its attack this mine has an immense advantage over all other kinds of *controlled* mines; while for the same reason it is superior to the observation ground mine in that absolute accuracy of position in planting is not needed, as is so imperatively necessary in the case of all mines which are intended to be fired by the observation method; but the electro-contact mine has the disadvantageous feature, as compared with the observation ground mine, of being liable to break adrift in heavy weather, owing to the fact of its being buoyant; compared with the combination buoyant mine the electro-contact one possesses the advantages of being simpler, and more easily planted, and retained in position.

The combination buoyant mine is the most objectionable form of controlled mine, and is only a forced condition of the small local effect of the explosion of a submerged charge of even the most powerful explosive, where a system of defence by submarine mines is required for deep-water channels.

In order of merit as to general simplicity, the observation ground mine comes first, then the electro-contact buoyant mine, then the combination contact ground mine, and lastly the combination buoyant mine.

All *controlled* mines, except the observation ground mines, labour under the further disadvantage of being very liable to be damaged by the constant contact of friendly ships passing in and out of a harbour where such mines are planted, as it is of course necessary to lay down the submarine mine defence some time previous to the actual outbreak of hostilities; a system of mooring has, however, been proposed which, if proved to be practical, will altogether remedy this serious defect, a description of which is set forth in Chapter III.

Different Systems of firing Submarine Mines.—A system of self-acting mines, whether mechanical, or electrical, can only be arranged to fire on actual contact with a ship, but in the case of the controlled mine there are three different methods by which they may be fired, viz:

1. By Contact { *a.* Automatically. / *b.* At Will.
2. At Will.
3. By Observation.

Automatic "contact" firing.—By this method of firing a controlled mine is for the time being converted into a self-acting mine, for a buoyant, or ground mine provided with a circuit closer is self-acting the moment the firing battery is connected up with the mine circuit, and the ground covered by mines in such a condition is then as dangerous to pass to friend or foe; the only difference between a field of self-acting and of controlled contact mines in an active state is, that in the former case the mine field is *always* unsafe, whilst in the latter case it can be rendered perfectly safe for the crossing of friendly ships, *i.e.* the mines composing the field can be at any moment placed in a state of inactivity by breaking, or opening the firing circuit.

This method of firing is the simplest, while it is the most certain, and most effective, for a ship must be either directly in contact with the (electro-contact) mine, or immediately over the (combination ground or buoyant) mine at the instant of explosion, and as it is automatic all chances of personal error are eliminated; further, this mode of firing is independent of the state of the weather, or of daylight.

At will "contact" firing.—In this case the actual firing of the mine charge is left to the option or will of the operator at the mine station; the contact effected between the mine and floating object, whether it be ship, vessel, or boat, &c., causes a bell to ring in the mine station, thus indicating that this particular mine has been struck, leaving to the operator the option of exploding it or not; the decision depending on the information received as to whether it is an enemy's war ship, or a dummy vessel sent in to explode the mine, or a boat, &c., in fact whether the colliding object is worth destroying.

At will firing.—This mode of firing is merely a means whereby any controlled mine may be exploded at any moment at the will of the operator, whether it be provided with a circuit closer or not, and if so provided, without any contact being made between a ship and the mine.

Observation firing.—This is a method of firing usually reserved for the simple observation ground mine, which by reason of the shallowness of the water, where a defence by submarine mines is required, prevents the use of a buoyant mine, or separate buoyant circuit closer case.

In these circumstances it is necessary to be able to know the actual moment when the hostile ship to be destroyed is immediately over the mine, so that the full effect of the explosion may be obtained, and this is effected either by some method of cross-bearings, or by the plane table, or other observation system, and when by one or other of these methods the ship is found to be actually over a mine, the latter can then be exploded either automatically at that instant, or at will.

This system of firing is defective for the following reasons:—

1. It requires *clear* daylight for its successful operation.

2. It necessitates each mine being most exactly moored in the position assigned to it.

3. Personal errors of the observers may cause a mine to be either fired prematurely or too late.

4. The observation stations are a source of weakness.

Under certain conditions it is impossible to resort to any other mode of firing; and therefore this mode of firing, with all its defects, is a necessary function of a system of submarine defence.

CHAPTER II.

DESCRIPTION OF SELF-ACTING MINES.

1. General remarks—A. Mechanical Self-acting Mines—2. Brook's Mine—3. The Percussion Fuze—4. The Chemical Fuze—5. McEvoy's Mine—6. Mathieson's Mine—7. Extempore Mine—8. B. Electrical Self-acting Mines—9. The Hertz Mine—10. McEvoy's Mine—11. The Naval Mine—12. Mooring Self-acting Mines.

GENERAL REMARKS.—The *self-acting* mine, of one sort or another, must enter somewhat largely into any system of harbour defence by submarine mines because of the impracticability of covering the whole space to be protected by *controlled* mines alone, owing to the great expense that would thereby be entailed both in regard to the first cost and the maintenance; while there are many positions in every harbour which are inaccessible to any but small vessels and boats, and therefore would not be worth the trouble and expense of planting with *controlled* mines, but which must nevertheless be in some manner blocked to the passage of an enemy's small craft, and this can be more easily and effectually secured by the use of *self-acting* mines than by any other means, notwithstanding their numerous and serious disadvantages as pointed out in the previous chapter.

The importance of this factor of submarine defence must be admitted by all on whom devolves the duty of providing for the proper protection of the seaports in every country, and yet but little has been attempted in the direction of obtaining a thoroughly efficient and reliable *self-acting* mine, though there are a great number of inventions of this description in the market from which to choose; at the present time England does not even possess in her submarine mine equipment a properly recognised form of mine of this class, good or bad.

The self-acting mines, descriptions of which here follow, have been chosen as representing in a marked manner the two classes, mechanical and electrical, into which they are divided, and each of the systems

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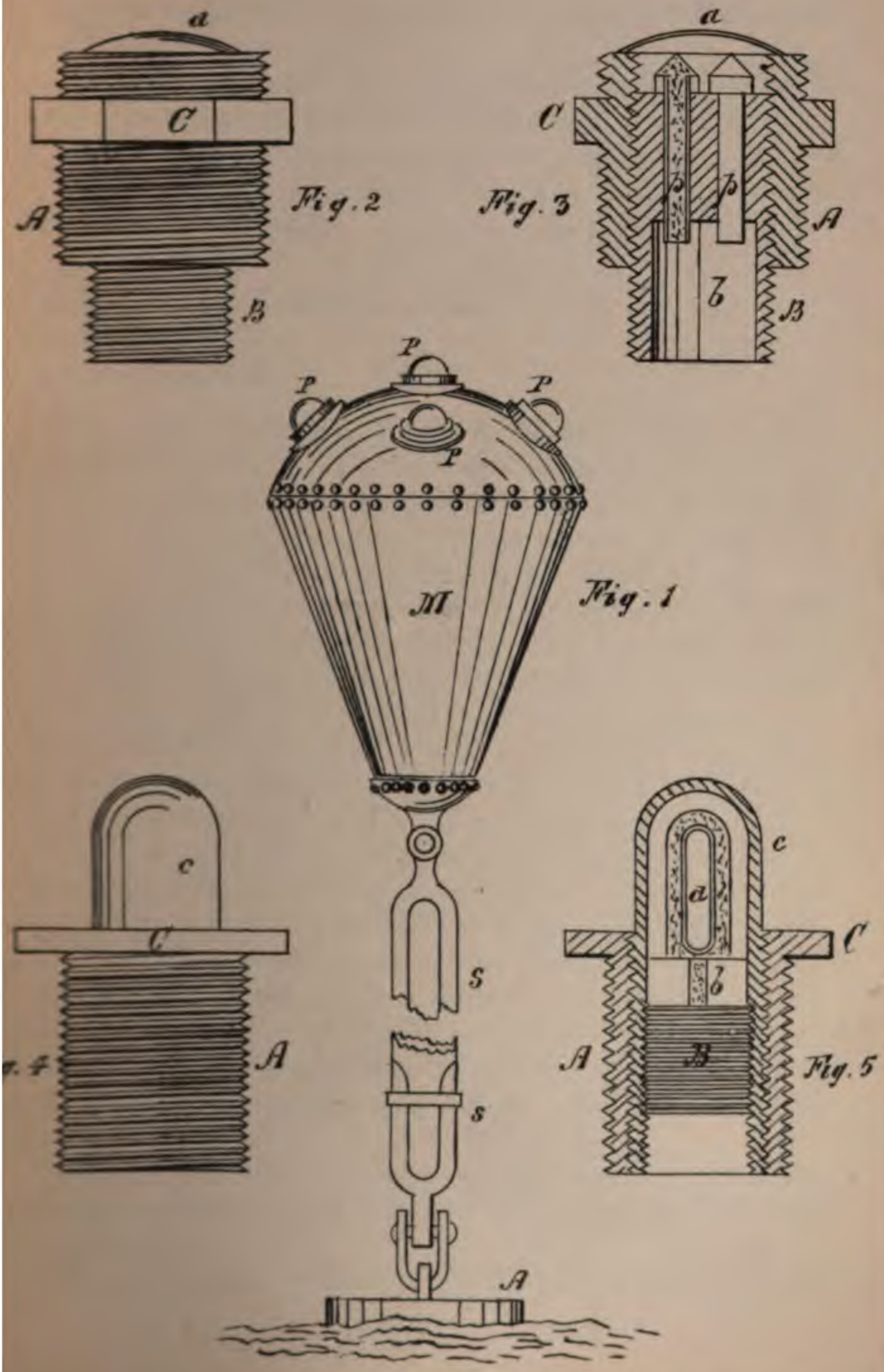


possesses the elements of safety in handling, and certainty of action in a sufficiently satisfactory manner to warrant their selection here as types of this useful class of mine.

A detailed consideration of the component parts which are common to both the self-acting and the controlled mine will be found in Chapter III., such as the mine case, fuze, and priming charge, &c.

A. *Mechanical Self-acting Mines.*

This class will include:

1. Brook's Mine.
2. McEvoy's improved Singer's Mine.
3. Mathieson's Mine.
4. Extempore Mine.

Brook's Mine—A sketch of Brook's mechanical self-acting mine is shown in Pl. I. at Fig. 1. It consists of a conical-shaped metal case *M* containing the charge of gunpowder, in the head of which five percussion, or chemical fuzes *P, P, P,* are screwed, so placed as to insure one or more of them being struck by the colliding vessel.

This is a type of mechanical mine that was used with considerable success by the Confederates in the American Civil War, and is included here because of its representing the best of that class of self-acting mines having percussion, or chemical fuzes, as its firing agent.

Percussion Fuzes.—One form of sensitive percussion fuze, which may be used in the foregoing system of mine, is shown in elevation at Fig. 2, and section at Fig. 3, Pl. I. It consists of an outer cylinder *A* of composition metal, having a screw thread cut on its outside for screwing it into the head of a mine case, and a bouching *C* provided with a sexagonal projection for applying a spanner to for the purpose of screwing the fuze into the mine case: this bouching is further provided with an external and an internal screw thread, the former being used for screwing on a safety cap, and the latter for enabling the internal cylinder *B* containing the primers *p, p,* being screwed up until contact is made between them and the copper cap *a*, when the fuze is required for action.

This copper cap is provided to prevent any moisture from reaching the priming composition, but is so thin that a slight blow will crush without breaking it.

The detonating composition used in this fuze by the Confederates was invented by General Rains: it consisted of a mixture of fulminate of mercury and ground glass, and was so sensitive that a pressure of seven pounds applied to the head of one of the primers was sufficient to explode it.

Chemical Fuzes.—An improved form of Professor Jacobi's chemical fuze suitable for the Brook type of mine is shown in elevation at Fig. 4, and in section at Fig. 5, Pl. I. This fuze, which was used in its original form by the Russians in 1854, consists of a metal case *A* provided with an external and internal screw thread: the former for fixing it into the head of the mine case, and the latter for the purpose of screwing on a safety cap. A sexagonal projection *C* is provided for screwing the fuze into the mine case by means of a spanner.

A small glass tube *a* containing sulphuric acid is enclosed in a lead cylinder *c*, and surrounding it (the glass tube) is a mixture of chlorate of potash and white sugar: *b* is a primer filled with mealed powder in connection with the charge in the mine. The action of this fuze is as follows: On a vessel colliding with a mine fitted with a number of these fuzes, and striking one of them, the lead tube *c* is bent over until it breaks the glass tube *a*, thereby causing the admixture of the sulphuric acid in the glass tube with the chlorate of potash and white sugar surrounding it, producing fire which ignites the primer *b* and so explodes the mine.

Defect of Mechanical Fuzes.—Mechanical fuzes, both percussion and chemical, which require a more or less sharp blow to insure their ignition, when applied to buoyant submarine mines may very probably fail to act in the event of an enemy's vessel being ***drifted*** over ground planted with mechanical (fuze fired) self-acting mines, as she would ***push*** away rather than strike the mine, and thus the ship might very possibly bend the lead tube without causing the breaking of the glass tube, and so avoid exploding the mine.

During the Civil War in America, and the late Russo-Turkish war, instances are recorded of vessels passing unharmed over ground planted with such mines, whilst other vessels passing over the same ground have afterwards caused the explosion of these self-same mines.

McEvoy's Mine.—This McEvoy mine is an improved form of the well-known Singer's mine, in which the displacement of a heavy weight from the top of the mine operates (mechanically) to fire the charge.

Plate II., Fig. 1, represents a vertical section of the McEvoy mine, nd Fig. 2 an enlarged one of the firing mechanism; *M* is the mine ase, *A* the heavy weight which rests in a seating provided for it on he top of the case, and which is prevented from falling, while the nine is being laid, by the papier-maché cover *a*, secured by screws to he top of the seating; *C* is the case containing the priming charge, nd the fuze *f*; into the base of the primer is screwed a tube carrying he firing apparatus, shown at Fig. 2; the whole is screwed into the ase of the mine case. The firing apparatus consists of the striker *c*, urrounded by a spiral spring *s*, and formed at its lower end to engage vith the hook piece *d*; a channel *N* is formed in the base piece *e*, uch that the hook piece *d* and striker *c* cannot disengage from each other so long as they remain in this passage; a piece of chain *L* onnects the weight *A* to the hook-piece *d*; between the head of the striker *c* and the cap of the fuze *f* a thin piece of flexible metal is interposed to prevent the ingress of water to the primer.

The action of this mine is as follows:—

On being moored in the position assigned to it, the papier-maché cover *a* becomes, after a few hours' soaking, soft and disintegrated, and in that condition frees the weight *A*, which can then be caused to fall out of its seating on the mine being struck by a passing vessel, but the seating is inclined in such a manner that the displacement of the weight (when free) cannot be brought about by any ordinary disturbance of the mine by the action of waves.

The mine having been planted a sufficient period of time to free the weight *A*, it is then in an active condition, and on being struck by a vessel will be exploded, by reason of the weight *A* being thereby displaced, which by its momentum in falling, will draw down the hook piece *d* and striker *c* (against or compressing its spiral spring *s*) until the interlocking parts are free of the channel *N*, at which instant the hook piece becomes disengaged from the striker, and the latter flies upward, due to the tension of the spiral spring, against a percussion cap at the base of the fuze, igniting the primer, and firing the main charge. In its original form (Singer) this mine was used with great success by the Confederates, and in its present improved form it may fairly claim to be one of the very best of the many *mechanical* self-acting mines extant, for, with ordinary care, it is safe to plant, and it exceedingly unlikely to fail to act when once in an active state.

while though there is a certain degree of risk attached in picking up such mines, yet with great care it is possible for those who plant the mines to execute this work in safety.

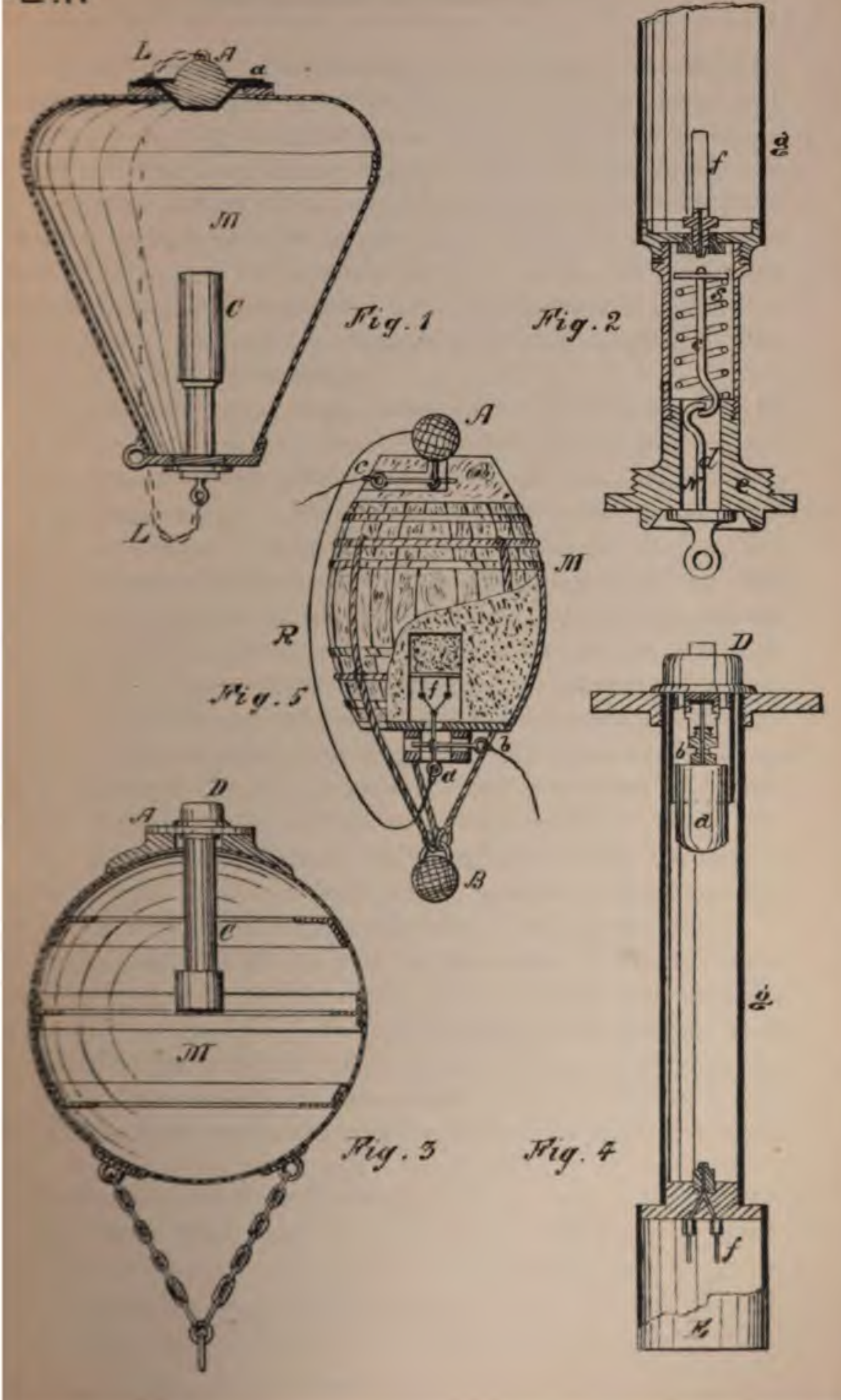
Mathieson's Mine.—The principle of Mathieson's mine is somewhat similar to the foregoing in so far that it is exploded by means of a falling weight disengaged by the action of collision between a vessel and the mine, but it differs very materially in respect to the details of construction, in that the whole of the action takes place *inside* the mine, that the weight is only made (by means of mercury) sufficiently heavy to effect the ignition of a percussion cap *after* the mine has been planted for some hours, and in that this weight has to be disengaged, not merely displaced.

Plate II., Fig. 3, shows a vertical section of this mine, and Fig. 4 an enlarged one of the firing apparatus. *M* is the mine case: *A* is the cover of the mine: *C* is a tube screwed into the cover *A*, of such a length as to give a sufficient fall to the hollow weight *a*, Fig. 4, to enable it to fire the percussion cap at the lower end of the tube, Fig. 4: a cover *D* is screwed into the upper part of the tube *C*: a chamber is formed in this cover in which mercury is placed: at the bottom of the chamber is an aperture which is closed by means of a zinc washer kept in place by means of a screw nozzle: in the lower end of this nozzle is screwed a vulcanite stem *b*, the lower end of which screws into the top of the hollow weight *a*: a groove is cut round the vulcanite stem: *f*, *f*, are fuzes: *E* is the primer.

The action of this mine is as follows:—

Immediately *before* the mine is planted, mercury is poured into the chamber, and the chamber is then closed by a screw plug; the mercury being then in contact with the zinc disc, causes it to slowly dissolve, but the disc will not be perforated before some hours have elapsed, in the meantime the mine will have been moored; after the zinc disc has been perforated by the action of the mercury, the latter will pour into the hollow weight *a* and thus make it of sufficient weight to perform its function of firing the percussion cap on falling thereon; on a vessel striking this mine the inertia of the now heavy weight *a* breaks off the vulcanite stem *b* at the point where it has been cut away for this purpose, and falling on the percussion cap, ignite the fuzes *f*,*f*, which fire the priming charge, and so explodes the mai charge.

PL. II



... & Co. PORTSMOUTH.

Extempore Mine.—Extempore apparatus (especially electrical) for submarine mining ought never to be required, and the use of such material is to be condemned, but it may possibly happen in a time of war, through some oversight or culpable negligence, that a ship may find herself unprovided with a supply of self-acting mines wherewith to obstruct a harbour or river mouth captured from the enemy, under which circumstances the construction of a number of extempore *mechanical* self-acting mines out of the material always to be found on board a man-of-war might be resorted to with advantage, or at least they would be better than nothing.

The extempore mine, a vertical section of which is shown in Pl. II. at Fig. 5, would, if carefully prepared, certainly act most effectively.

It is formed on the principle of the Singer mine, and acts in a precisely similar manner. The mine case *M* is an ordinary cask, which is made water-tight by two good coats of pitch; the weight *A* is a round shot enclosed in a net, and is kept from falling off its seat while being moored, by means of the toggle *C* which passes through the eye of a rope spliced into the lower part of the net round the weight *A*; the firing apparatus consists of two friction tubes *f*, attached to a pin *a*: the rope *R* connects the weight *A* to the firing-pin *a*: additional safety is secured by means of the rod *b*, by which, if the weight *A* were to fall prematurely before the mine was laid, the sudden pull would come on this safety rod *b*, and not on the friction tubes.

The safety rod *b* is drawn out immediately before the mine is lowered into the water, and the toggle *C*, to which a long lanyard is attached, is only pulled out when the mine is properly moored.

As gunpowder would be used for the charge of this extempore mine, the greatest attention must be paid to making the case water-tight, and especially the hole in which the firing pin is inserted; whilst care must be taken that the weight and its fittings are so arranged as to render the displacement of the weight perfectly certain (after the toggle *C* has been withdrawn) on the striking of the mine by a vessel.

B. *Electrical Self-acting Mines.*

This class will include:—

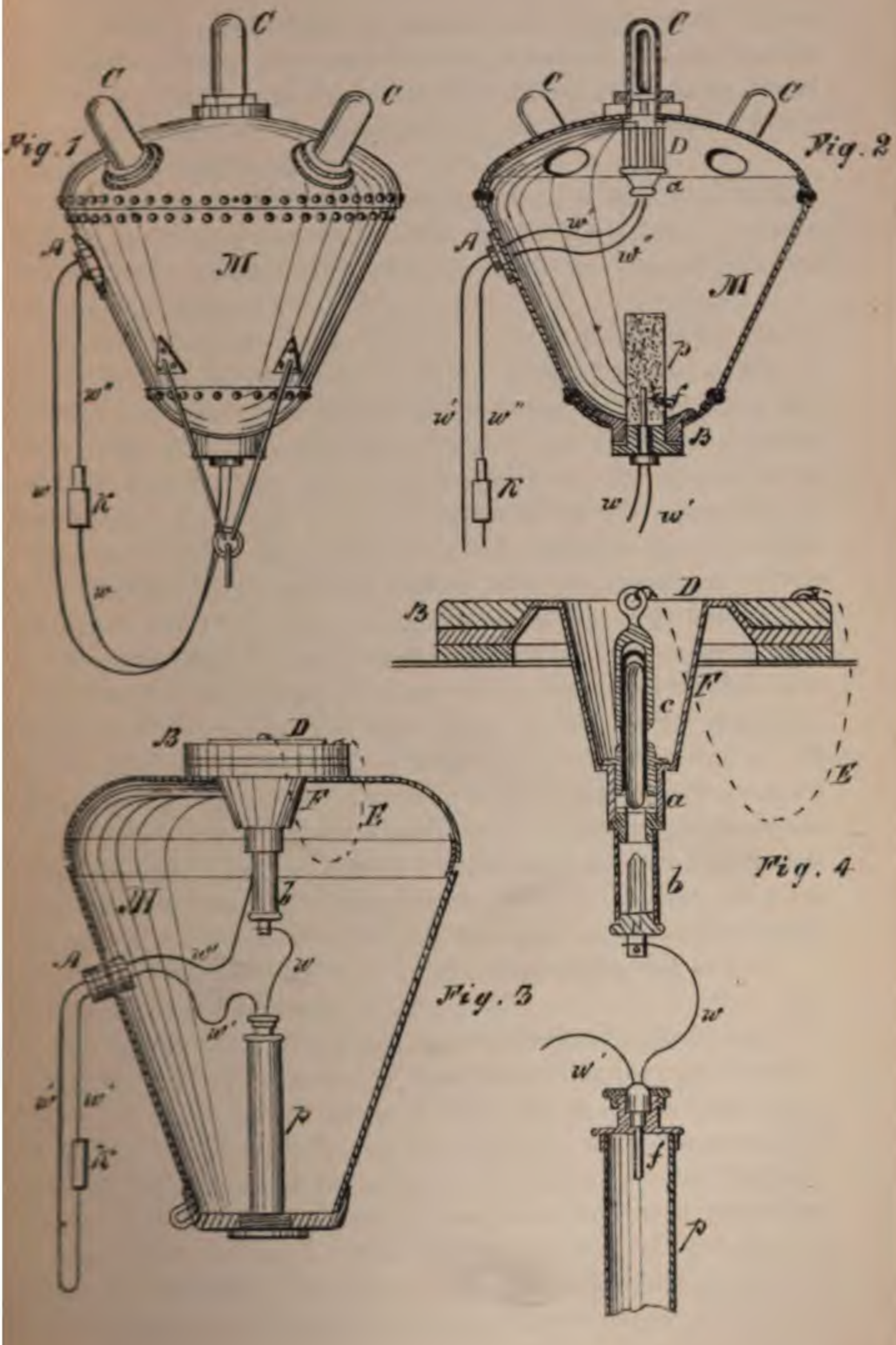
1. Hertz' Mine.
2. McEvoy's Mine.
3. Naval Mine.

Hertz Mine.—The Hertz electrical self-acting mine was used in considerable numbers by the Russians in the Russo-Turkish war (1877–8), more especially on the Danube, where on one occasion a Turkish gunboat was sunk by colliding with one of these mines.

The Hertz mine is shown in elevation and section in Pl. III. at Figs. 1 and 2. *M* is the mine case: *A* the loading hole: *B* the base plug; *C*, *C* are cylinders screwed into the case *M*, at such positions as to afford them the greatest possible chance of being struck by a vessel coming into contact with the mine: each of these cylinders *C*, *C*, consists of a lead tube enclosing an hermetically sealed glass tube containing a chlorate of potash mixture: for safety purposes a brass cylinder is screwed on over the lead tube: directly beneath each of these lead tubes, *C*, *C*, on the inside of the mine is fixed a thin brass case *D*, closed at its inner end by a disc of wood *a*: this case contains several pairs of plates of carbon and zinc in the form of a cell: *p* is a copper cylinder fitted to the base plug which contains the detonating fuze *f*, and the priming charge: two insulated wires *w* and *w'* are connected to the two fuze terminals, one, *w'*, being led through the loading hole plug and connected to the five zinc terminal wires of the five cells: the other wire *w* is connected to one terminal of a safety key *K* on the outside of the mine, the other terminal of which is connected by the wire *w''* led through the loading hole plug to the five copper terminal wires of the five cells: thus a complete electrical circuit is formed between the five cells and the fuze through the safety key *K*; and with this key closed it only needs the addition of the electrolyte (contained in the cylinder *C*) to bring into action an electric current of sufficient strength to fuze the platinum wire bridge of the fuze and to explode the mine: with the safety brass cylinders removed, this effect would be produced by a vessel colliding with the mine, or rather with one or other of the lead cylinders *C*, *C*, *C*. This mine is provided with two means of safety, first the exterior brass cylinders, and secondly the safety key (which may be of any suitable form), and it is necessary in planting these mines to exercise care in ascertaining that the brass safety cylinders are removed, and also that the safety key is closed, or otherwise the mine, in which either of these points have been left unattended to, becomes neither more nor less than a dummy.

It is quite possible for a vessel drifting with the tide to pass over such a mine planted at too great a depth below the surface, and

PL. III



only graze one of the lead projections, and thus bend it without breaking the interior glass tube. Amongst several of these Russian Hertz mines picked up by the author at Soulina in 1877, one was found with a lead tube bent considerably out of the perpendicular and yet with the glass tube intact.

McEvoy's Mine.—The McEvoy electrical self-acting mine, though in principle of action somewhat similar to the Hertz mine, is a very decided improvement on it, as will be readily understood from the following description.

A vertical section of the McEvoy mine is shown in Pl. III. at Fig. 3, and an enlarged section of the firing apparatus at Fig. 4. *M* is the mine case: *p* is the priming case carrying the electric fuze *f* at the top: *F* is a cup-like piece inserted into the top of the mine case, and secured there with a water-tight joint, and having at its lower or inner end a socket into which the ferrule *a* is screwed: *B* is a flat weight fitting into a seat provided for it in the top of the mine case: this seat is so inclined that no ordinary disturbance of the mine when moored is likely to displace the weight: *c* is a metal cap fitting over a lead tube, inside of which is a glass tube, and connected by a chain *E* to the weight *B*: a ring or cover of papier-maché *D* is placed over the weight and screwed to the top of the cup-piece, for the purpose of preventing the premature dislodgement of the weight during the process of mooring: *b* is a primary cell composed of carbon and zinc plates, the electrolyte for which is placed in the glass tube: *w*, *w'* are two insulated wires, *w* connecting one terminal of the fuze to one pole of the battery, while *w'* connects the other terminal of the fuze, and of the cell through a key *K* on the outside of the mine case, after passing through a water-tight joint at *A*.

The action of this mine is as follows:—

The key *K* being closed, and the papier-maché cover being disintegrated (which happens two or three hours after the mine has been moored) the mine is thus rendered active, and on a vessel striking it, the weight *B* will be dislodged, and in falling will, by means of the chain *E*, and the metal cap *c*, cause the bending of the lead tube, and consequent breaking of the interior glass tube, thus permitting the electrolyte contained therein to flow into the cell *b*, creating a current of electricity through the fuze *f*, sufficiently powerful to ignite it, and so fire the priming charge, and explode the mine.

In planting this mine only one, instead of two precautions as in the Hertz mine, is necessary to insure its not being a dummy one when required for action, viz. the closing of the key *K*, which is opened for the purposes of safety during the mooring of the mine. The falling weight with single lead tube is a great improvement over the five lead tubes projecting from the Hertz mine case, as it obviates the necessity of actual contact (a blow) between one of them and the colliding vessel to secure the breaking of the glass tube containing the electrolyte, and it is extremely unlikely that any failures to act will occur with this self-acting mine.

Naval Mine.—This self-acting mine is the form adopted by the naval torpedo authorities, and its principle is a modification of the McEvoy mercury circuit described in the first edition of this work, and which has been very generally used in the Danish torpedo service. A sectional elevation of this mine is shown in Pl. IV. at Fig. 1, and an enlarged section of the circuit closer at Fig. 2.

M is the mine case, *C* the mercury circuit closer, *S* the safety apparatus: *B* the firing battery, which consists of two Leclanché cells: *E* is a cavity in the base of the mine case, in which the safety apparatus is placed, and is closed by a diaphragm: *F*, *F*, *F*, is a wooden casing in which the charge of gun-cotton is placed. The safety apparatus *S* is arranged as follows: An ebonite cylinder, closed at both ends by a screw ebonite plug, contains two pieces of insulated wires, terminating in two pieces of copper, which are kept apart by a papier-maché wad. On the mine being moored in the water, the papier-maché wad is gradually and slowly disintegrated and dissolved by the action of the water admitted into the cavity *E*, and thus, by holes, into the plug *S*; a spring then forces the two copper terminals of the wires together, an india-rubber disc at the same time closing the holes.

The circuit closer *C*, Fig. 2, consists of a cast-iron cup in which the mercury *a* is placed, just filling the lower part, with the terminal *t*: a plug *b* with its terminal *t'*; the action of this circuit closer is as follows: On the mine being struck by a vessel, the shock of the collision causes the mercury to be thrown into contact with the plug *b*, thereby closing the firing circuit through the wire *w''* connected to the terminal *t'*.

The arrangement of the mine is as follows: The primer *D*, circuit closer *C*, and firing battery *B* are fixed to the upper part of the wooden, PL. IV.

Fig. 1

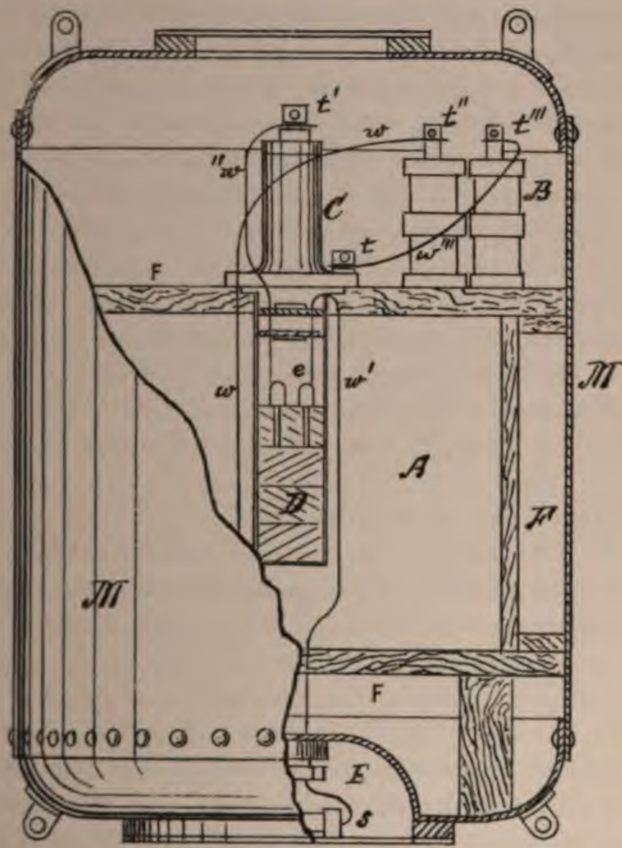
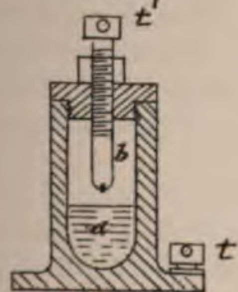


Fig. 2



charge case *F*, *F*, and the safety apparatus *S* is placed in the cavity *E*: the wire *w* is connected to one terminal *t''* of the battery, the other terminal *t'''* being connected by the wire *w'''* to the terminal *t* of the circuit closer *C*: the wire *w'* from the safety apparatus *S* is connected to the fuze: the wire *w''* connects the fuze to the terminal *t'* of the circuit closer *C*: the wires *w* and *w'* are led through a water-tight joint from *E* into the mine case: the firing circuit between the fuzes and the battery is thus broken in the safety apparatus, until the papier-maché wad is dissolved, and in the circuit closer until the mine receives a blow or shock, such as being struck by a ship.

This mine has been known to fail to act in many instances, due to the act of collision between the vessel and the mine not causing a sufficient shock to throw the mercury up in contact with the plug *b*, and it has a further objection in that it is peculiarly sensitive to the explosion of a counter-mine; in fact it is very inferior as an *electrical* self-acting mine to either the "Hertz" or "McEvoy" previously described.

Mooring Self-acting Mines.—This description of submarine mine should on no account be planted in deep water channels, or in places where strong tides, or rapid currents are to be met with, on account of the danger to all vessels, friendly or otherwise, arising from the breaking adrift of one or more of these self-acting mines: and it is impossible to ascertain, as can be done in the case of the *controlled* mine, whether such a mishap has occurred.

A mushroom anchor and single steel wire rope would therefore be sufficiently strong moorings to maintain this class of mine in position, but it is necessary to repeat here that every precaution must be taken in executing this work.

To facilitate the planting of self-acting mines an automatic method of mooring them has been devised, whereby they moor themselves automatically at any fixed depth below the surface of the water.

With this system of mooring the necessity of knowing the actual depths of water in any place where it is desired to plant such mines, so as to secure the proper length of mooring rope for each, is entirely obviated.

This method of mooring was invented by Lieut. Petrouski of the Imperial Austrian Navy, and other methods of performing the same operation have been designed by Captain McEvoy and others; these designs have so far been kept a secret, but the pressure of water at any particular depth at which the mine is to be moored beneath the surface being known, and taking into consideration the fact, that it is possible to use wire of very small diameter for the anchoring of mines under the exceptional circumstances admitting of the adoption of this system of mooring, the problem of how to effect this object does not present any difficulties to the skilled engineer.

The various methods of mooring all classes of mines will be found fully described and illustrated in the following chapter.

CHAPTER III.

DESCRIPTION OF CONTROLLED MINES.

THE *Component Parts of a Controlled Mine.*—This chapter will be devoted to the consideration of the Controlled Mine, not of the system of defence with such mines, but only in so far as concerns the component parts of the mine itself, and which are as follows:—

A. The mine case.
B. The circuit closer.
C. The fuze.
D. The cable.
E. The junction box.
F. The moorings.

A.—THE MINE CASE.

The form and mode of constructing the case of every *submarine* mine must be that which will best enable it to fulfil the essential condition of withstanding a pressure of water, the measure of which depends on the depth of submergence, and to remain perfectly water-tight.

It is also important that the means provided for loading a mine with its charge, and for fixing in its circuit closer, be such that this work can be quickly and readily performed.

In the case of all *buoyant* mines the dimensions of the cases must be such that a considerable amount of *excess* buoyancy is provided by which to maintain the mine in a stationary position when moored.

Then the nature of the explosive agent which is intended to be used as the charge is an important consideration.

For explosive compounds such as gun-cotton, dynamite, &c., the mine case should not be of greater strength than is actually necessary to enable it to fulfil the condition as to water-tightness; but for charges of gunpowder and such like explosive mixtures, additional strength of case is necessary to insure the full explosive effect being obtained.

Spherical Shape.—The shape of the case best suited for all the purposes of a *buoyant* submarine mine is that of a sphere, and this is now the recognised form; hitherto the case was constructed in the form of a cylinder, and also conical, the spherical shape, though considered to be theoretically the most perfect, having previously offered considerable difficulties in its construction, which have, however, now been entirely overcome.

There are three kinds of buoyant mines now in use, which are distinguished by the size of their charge, viz. the 50 lb., 100 lb., and 500 lb. mine.

The 50 lb. case is used with the 500 lb. mine to carry the circuit closer, when they together form the "combination" buoyant mine: the 50 lb. mine case is in fact what is termed the "buoyant circuit closer case."

The 100 lb. case is used for the "electro-contact" mines.

The 500 lb. case may be used either as a contact mine, when it is combined with the 50 lb. case, or as a simple buoyant mine fired by observation.

All these cases are similarly constructed, differing only in dimensions and strength of material; at Fig. 1, Pl. V., a sketch of a 500 lb. mine case is shown.

This form of case is constructed in two hemispheres, *A* and *B*, with an opening in the lower one at *C*: the two halves are joined together

PL.V.

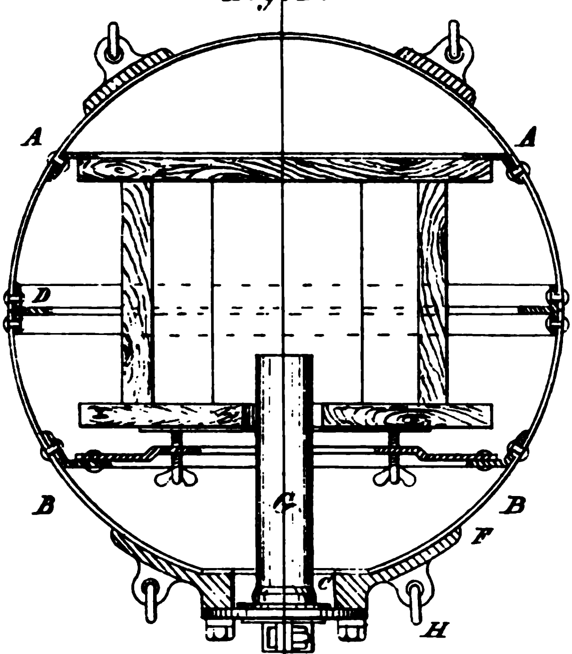


Fig. 1.

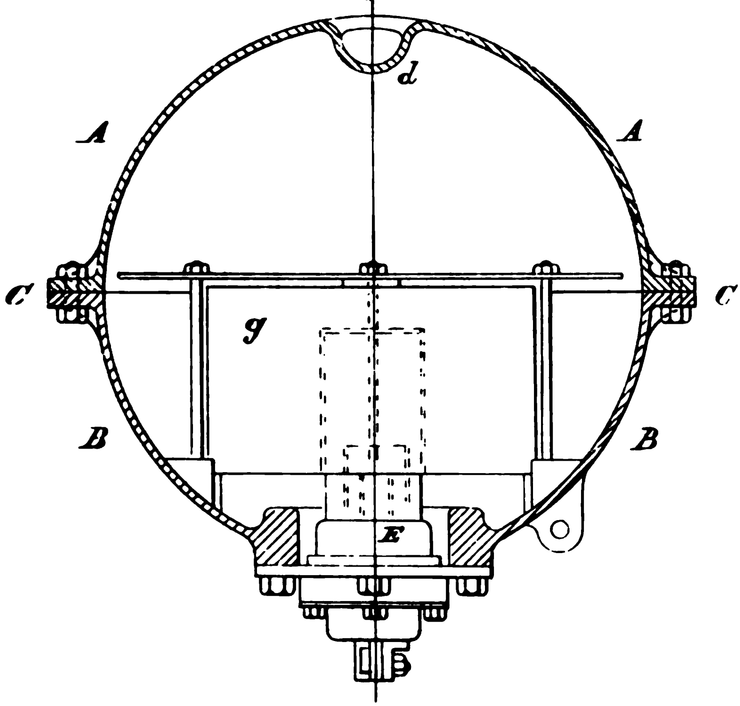


Fig. 2

and form the spherical case by means of an inside web plate of T iron *D*, which is riveted to the two hemispheres with four rows of rivets for the 100 lb. and 500 lb. case, and two rows of rivets for the smaller 50 lb. case; after the sphere has been formed, a flanged collar *F* is riveted on, which is used for bolting on the base piece carrying the circuit closer *G*: the opening in this collar is also used for loading the mine with its explosive charge; *H, H,* are lugs with eye-bolts for shackling on the mooring chains.

Particulars of these mine cases are as follows:—

TABLE I.

	Weight empty.	Excess buoyancy.
	lbs.	lbs.
50 lb. case . .	350	200
100 " " . .	700	350
500 " " . .	1,050	500

Gibbins' Spherical Case.—A form of spherical mine case as devised by Sergeant P. Gibbins, late R. E., is shown in section in Pl. V. at Fig. 2.

As constructed by the firm of Messrs. Latimer Clark, Muirhead & Co., it consists of two hemispheres, *A* and *B*, of iron, steel, or malleable cast-iron, which instead of being riveted together into one whole sphere, are flanged as at *C*, and bolted together, a water-tight joint being made by means of india-rubber, or such like material; the upper hemisphere *A* is provided with a sunken eye-bolt *d*: the lower hemisphere has an opening in which is inserted the base piece with circuit closer and priming charge case *E*: in the interior of this lower half is fixed an iron box or case *g*, in which is placed the main charge of gun-cotton or other explosive.

The object of this form of case is to simplify the loading and fitting up of the mine, as well as to enable the mine to be always kept loaded, but these advantages are secured at the cost of a possible leakage at the joint *C*, and the possibility of the flange excrescence aiding an enemy in the work of clearing away the mines of the defence.

Cylindrical Shape.—As a great number of the old pattern cylindrical mine cases are still in use, it is necessary to give some details of their construction, size, &c.

There are four descriptions of these cases, viz., a 100 lb., 250 lb., 500 lb. and 500 lb. The 100 lb. case is used for the "electro-contact" mines, and is shown in section in Pl. VI. at Fig. 1; it consists of a wrought-iron cylinder of No. 12 B. W. G., with flat ends, and being very thin is tinned inside to ensure the joints and rivets being watertight, and is enclosed in a wooden jacket *A* to give it the necessary buoyancy, and this jacket also acts as a protection against the blows of vessels colliding with the mine; *C* is the circuit closer, *F* the fuze case, *H* is the mooring chain ring.

The 250 lb. and one of the 500 lb. cases are used as ground mines, and the other 500 lb. case as a buoyant mine.

These three cases are similar in construction, being formed of an iron cylindrical body with dished ends, but they differ in size and thickness of plate.

A section of a 500 lb. mine case is shown in Pl. VI. at Fig. 2, where *M* is the mine case, *A* the fuze and mouthpiece.

Particulars of these four cases are as follows:—

TABLE II.

	Thickness of plate.	Diameter.	Weight loaded.	Buoyancy.	
				Excess.	Loss.
		inches.	lbs.	lbs.	lbs.
100 lb. case . .	12 B. W. G.	14	..	140	..
250 " " . .	$\frac{3}{16}$"	24	520	..	150
500 " " . .	$\frac{1}{4}$"	30	1,000	..	200
500 " " . .	$\frac{3}{16}$"	32	850	150	..

McEvoy's Dome-shaped Case.—The most suitable form of case for ground mines has been found by practical experience to be hemispherical, or dome-shaped, the base of which forms the mine's anchor or mooring weight. A sketch of one of these ground mine cases as designed by Captain McEvoy is shown in Pl. VI. at Fig. 3, where *M* is the mine case, *A* the loading hole, *P* the primer.

.VI.

Fig. 1

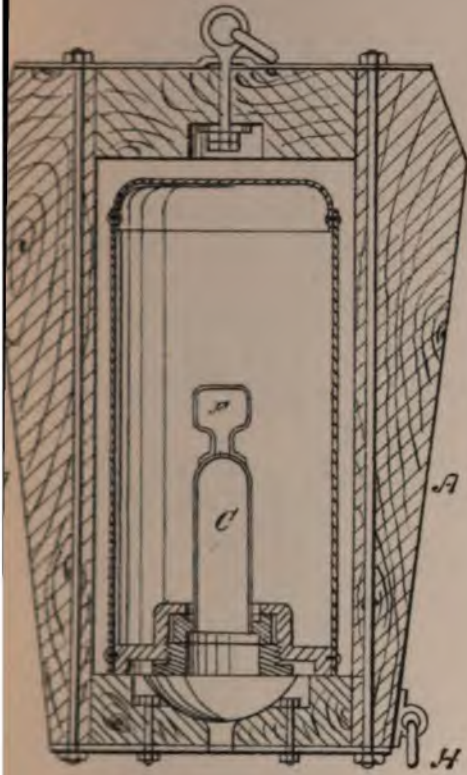


Fig. 2

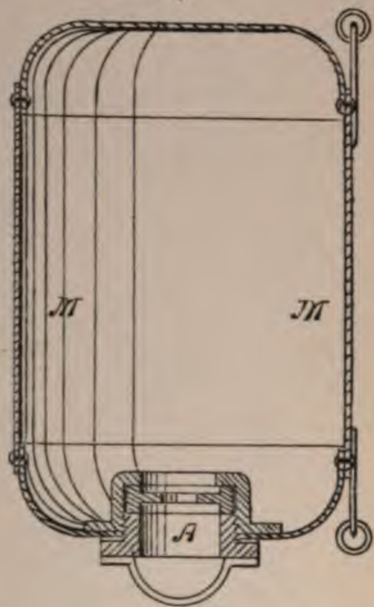
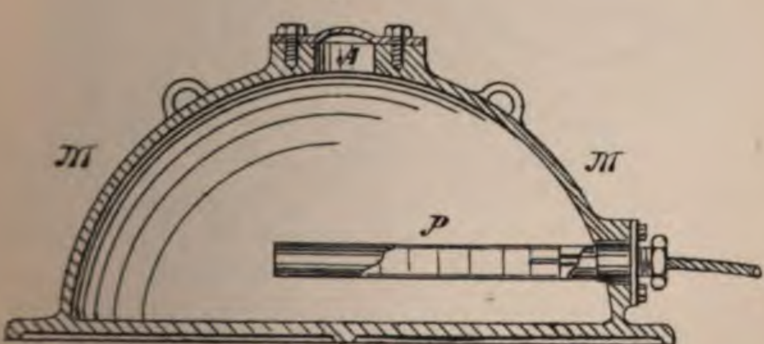
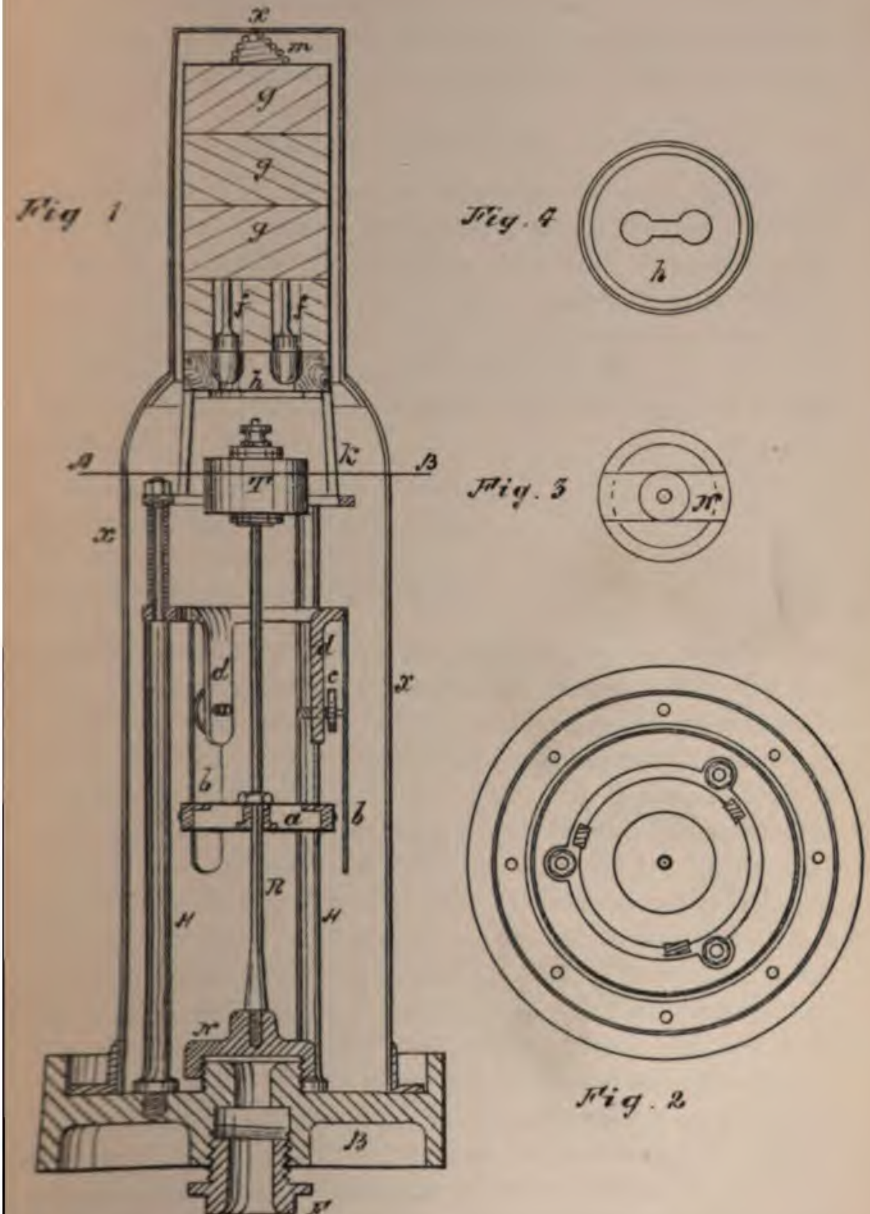


Fig. 3.



L.VII



PORTSMOUTH.

Three sizes of these mine cases are made, viz., 500 lb., 750 lb., and 1000 lb.

They are constructed of cast-iron, from $\frac{5}{8}$ in. to 1 in. in thickness, according to the depth at which they are to be submerged, and their weight varies from 800 lbs. for the smaller one to 2000 lbs. for the larger one.

B.—The Circuit Closer.

Controlled buoyant or ground submarine mines to be fired by contact require an electrical instrument placed either in the mine case itself, or in a separate buoyant case which shall automatically put in circuit the firing battery (if it be so desired) on an enemy's vessel colliding with the mine, or the buoyant case thus fitted, and this electrical instrument is termed a "circuit closer."

There are four kinds of circuit closers in general use at the present time, viz.:—

1. Mathieson's inertia circuit closer.
2. Gibbins' spiral spring circuit closer.
3. Chatham relay circuit closer.
4. McEvoy's magneto circuit closer.

Of these four circuit closers, the first one may be considered as practically superseded by one or other of the remaining three, but as a vast number of them are still in use, it has been necessary to include its description with the other more modern and improved ones.

Mathieson's Inertia Circuit Closer.—This form of circuit closer is the one that has hitherto been used by the English Government in connection with their system of submarine mine defence, but its place is now taken by the new Chatham circuit closer described at page 49.

This circuit closer is illustrated in Pl. VII., where Fig. 1 is a sectional elevation; Fig. 2 a plan through *A B*; Fig. 3 a plan of the spindle bridge; and Fig. 4 a plan of the ebonite and brass spindle disc.

This circuit closer consists of a gun-metal dome *x, x, x*, screwed on to a metal base *B*; *N* is a metal bridge screwed on to the base *B*; *H, H*, are brass columns supporting a circular ebonite piece *h*; *R* is a spindle carrying a weight *T*, and screwed into the bridge *N*; *b, b*, are three contact springs; *c* are adjusting screws to regulate the sensitiveness of the apparatus; *a* is a brass contact piece attached to the spindle *R*; *f, f*, are the fuzes; *g, g*, the priming charge of gun-cotton.

The Armstrong Relay.—In the simple form of this circuit closer for electro-contact mines, there was no means of testing, the circuit being broken at the contact springs. This relay, devised by Colonel R. Y. Armstrong, R.E., was introduced to obviate the defect.

It consists of a cylindrical block of box-wood having three holes bored longitudinally in it to admit of it fitting over the three columns of the circuit closer. Horse-shoe magnets are fitted at the top and bottom. A high and a low resistance coil are wound one over the other in opposite directions round a hollow bobbin. An armature or tongue is pivoted in the hollow bobbin, one end of which works between two contacts.

Testing.—For this purpose a vibrating movement of the tongue is set up, which continues so long as the proper (positive) current is maintained, and which is indicated on shore by the telephone.

Should the mine be struck while the SIGNALLING (negative) current is on, the current passes through the low coil wire direct to earth. The tongue is thus brought over to the left contact stop, and the current being negative, the tongue is held over there; the mine may then be fired through the low resistance circuit.

Gibbins' Spiral Spring Circuit Closer.—A vertical section of this circuit closer is shown in Pl. VIII., Fig. 1, a plan of the relay at Fig. 2, and of the contact piece at Fig. 3; it consists of a base of malleable cast-iron *A*, on which are mounted the pillars *B*, *B*, carrying a metal table from which depends a helical metallic spring *a*, and an electro-contact disc *C*: this disc is insulated by an ebonite block from the spring *a*: the contact springs *D* are supported on the base *A* as near to the insulated disc *C* as is necessary for the contact screws *b*, *b*, on disc *C* to strike the springs *D*, and close the circuit whenever the mine is struck by a passing vessel: *E* is a relay, above which is fixed a wooden platform *F*, supported on the pillars *B*, *B*, which carries the detonators and the priming charge *G*, and kept firmly pressed down by a disc and spiral spring *D'*: the whole of this apparatus is enclosed in a drawn steel envelope *H*, hermetically closed at the top, and provided with a flange and screw collar. The relay *E* which is shown in plan at Fig. 2 consists of an electro-magnet *K*, and armature *e*: the core of the magnet is wound with fine wire of some 2000 ohms resistance, and also with a thick wire of some 4 ohms resistance.

The action of this circuit closer is as follows: When the mine is

GIBBINS' CIRCUIT CLOSER.

PL.VIII.

Fig. 1

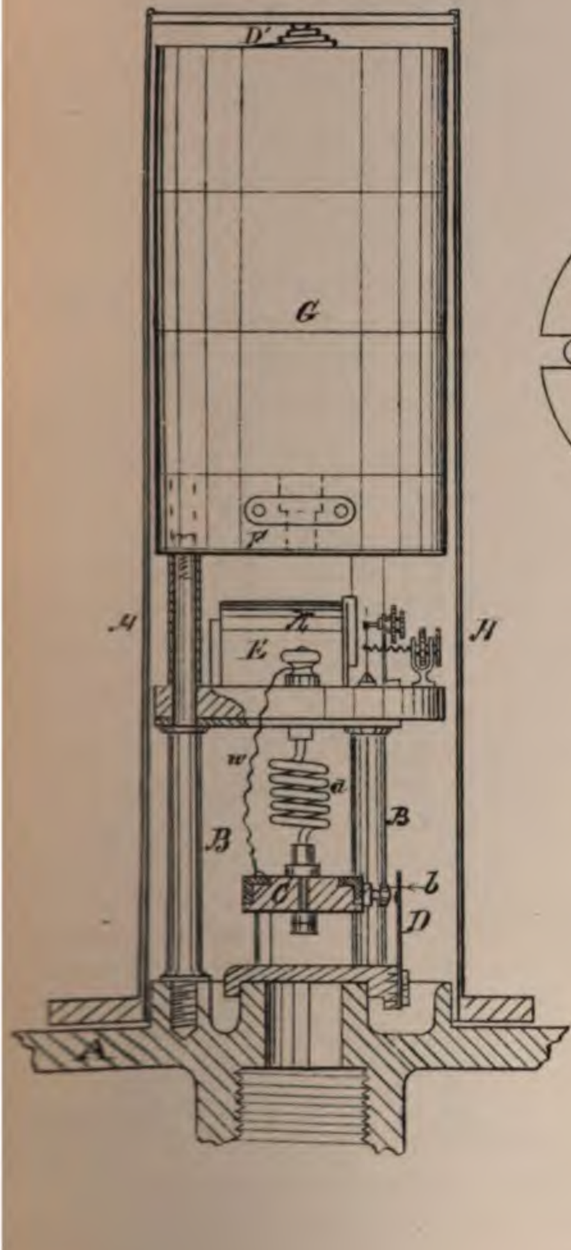
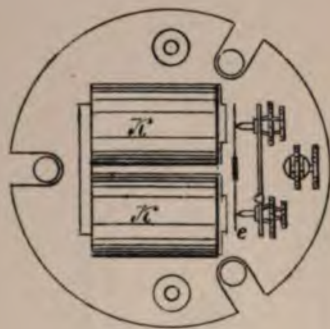


Fig. 2



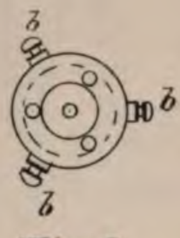


Fig. 3.

PL. IX

Fig. 1

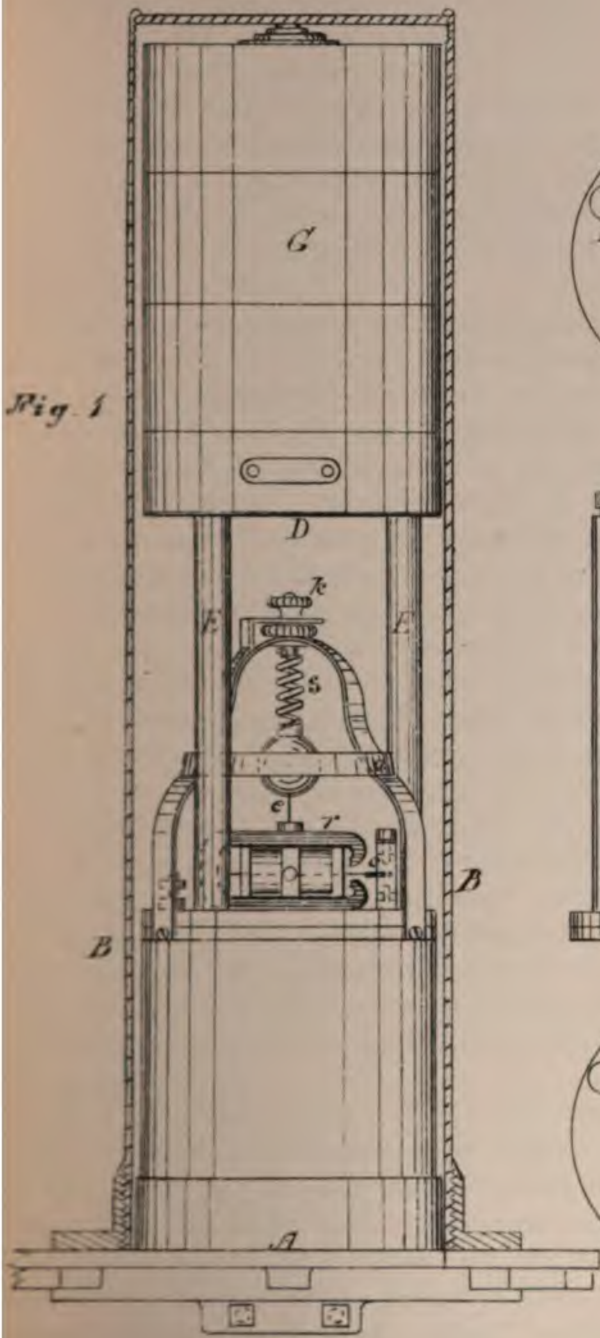
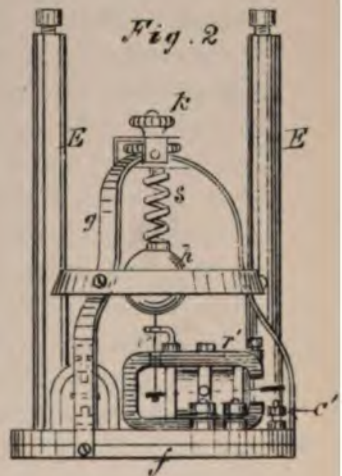


Fig. 4

Fig. 2



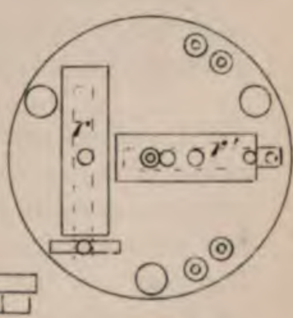


Fig. 3

placed in position, a small signalling current is kept constantly passing through the detonating fuzes, and thence through the *fine* wire coil of the relay to earth, and by reason of the great resistance of the circuit the detonators are not exploded, the armature is not attracted, and the condition of the detonators may be tested electrically, or signals may be sent through the circuit without danger. This current also passes through an electro-magnetic signalling shutter on shore, but the current, besides being too feeble to fire the mine, is also too feeble to drop this shutter.

This circuit of low resistance and a contact piece on the relay is so arranged that when a testing current of greater strength is sent through the fine wire coil the armature is attracted and completes the circuit, so that the current passes not only through the fine wire coil circuit, but is also shunted through the circuit of low resistance, the result being that the resistance of the circuit is reduced by 2000 ohms, and the galvanometer on shore shows the completion of this short circuit by its greatly increased deflection, thus proving that the whole circuit is in good electrical condition and ready for firing. If it be desired to fire the mine, a still stronger (firing) battery is put in circuit, the current from which first closes the contact through the fine wire coil, attracts the armature, and closes the circuit through the thick wire-coil, and explodes the mine. If at any time therefore the mine is struck by a passing vessel, the contact disc *C* is thrown into vibration, and, momentarily touching the contact springs *D*, it completes a short shunt circuit, by means of the wire *w* between the contact springs and the earth, and this current thus short circuited is sufficiently strong to drop the shutter on shore, and thus indicate that the mine has been struck, and the operator can then fire the mine as desired.

This mine can be arranged as an electro-contact mine, that is, to explode instantaneously on being struck by a vessel, by *short circuiting* the firing key on shore.

Chatham Relay Circuit Closer.—This circuit closer has been lately adopted in the English torpedo service, and is shown in vertical section in Pl. IX., Fig. 1: *A* is the steel base; *B* a steel envelope enclosing the whole apparatus, *i.e.* the circuit closer instrument, the fuzes, and the priming charge; *D* is a platform carrying the two fuzes, and priming charge *G*, supported by the pillars, three in number, *E*, *E*: the circuit closer instrument shown at Fig. 2 consists of an insulating base *f* supporting a tripod frame of brass *g*; from the apex of this tripod is suspended a spiral spring *s*, and inertia ball of brass *h*; *k* is the screw for adjusting the tension of the spiral spring *s*; on the base *f* are fixed two Armstrong relays *r*, *r′*, Fig. 3, placed at right angles to one another. These relays consist of a horseshoe magnet within the enclosed space of which is placed a hollow bobbin of wire, and pivoted within the bobbin is a tongue: for the relay *r*, this tongue has an upper and a lower contact *c*, while the tongue of the relay *r′* has only a lower contact *c′*; the larger relay *r* is wound with wire of 2000 ohms resistance, while the smaller relay *r′* has only a resistance of 5 ohms.

The inner end of the tongue of the relay *r′* is attached by a piece of silk *e* to the inertia ball, so that in the event of the ball being caused to oscillate, the tongue is pulled into contact with the contact piece *c′*.

At Fig. 3 a plan of the insulating base *f* is shown, where *r* and *r′* are the two relays placed at right angles to one another. A plan of the circuit closer at the apex of the tripod is shown at Fig. 4, where *g*, *g*, *g*, are the brass arms of the tripod, *E*, *E*, *E*, the pillars, and *k* the spiral spring adjusting screw.

The mode of connecting up the circuits of this circuit closer differs for *contact* and *at will* firing, and as it is one of the so-called "secrets," and is besides unnecessarily complex, the author has thought it advisable to leave out any description of it.

McEvoy's improved Inertia Circuit Closer.—This McEvoy circuit closer has been especially designed to resist counter-mining, *i.e.* to withstand the shock of a counter-mine or other mine exploded in its immediate neighbourhood, the effect of which is, in the case of other circuit closers, to cause them to act prematurely, and this certainty of inaction, except at the proper moment, is secured by arranging the inertia weight so that it cannot move in a *vertical* direction.

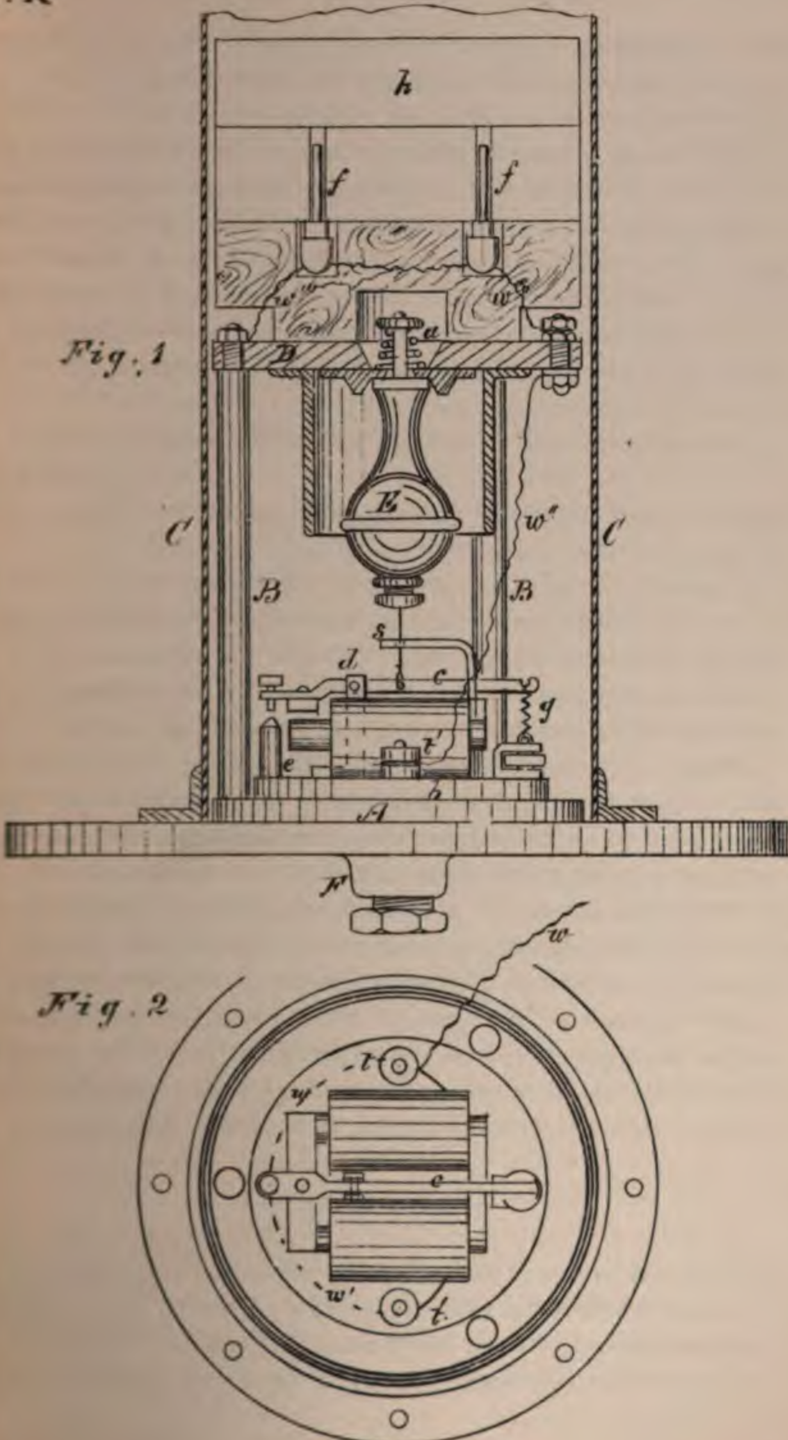
This circuit closer is shown in Pl. X., where Fig. 1 is a sectional elevation, and Fig. 2 a plan of the base plug.

A is the metal base plug attached by studs to the steel envelope *C*, *C*,: *B*, *B*, are brass columns supporting a platform *D*: *E* is the inertia weight suspended from the platform *D*, and adjustable to any degree of sensitiveness by the thumb-screw and spring *a*: an electro-magnet placed horizontally is fixed to the ebonite base *b*, having its arm

L. X

Fig. 1

Fig. 2



ture *c* pivoted at *d*: one end of this armature has an adjusting contact screw, and at the other end is a spring and set screw *g*, to hold the former off the contact piece *e*: the armature is attached to the inertia weight *E* by a silken cord *s* working through a guide bracket: the fuzes *f*, *f* are connected in series. The circuit is formed as follows: the bobbin wires of the electro-magnet are connected to the terminals *t*, *t'*: an insulated wire *w* connects terminal *t* with the contact screw of the armature *c*, and another insulated wire *w'* connects terminal *t'* with the contact piece *e*: a further insulated wire *w''* connects one terminal of the fuzes *f*, *f*, to the terminal *t'*: the other terminal of the fuzes is put to earth by the wire *w'''*: the core of the main cable is led through the water-tight screw joint *F*, and connected to the terminal *t*.

The current from the signalling battery (the mine being at rest) passes through the main cable wire, through the high resistance of the bobbins to the terminal *t'*, thence by the wire *w''*, through the fuzes *f*, *f*, and to earth by the wire *w'''*: the battery being also put to earth, this completes the circuit. This signalling current is not powerful enough to cause the armature *c* to be drawn down in contact with *e*, or to work the instrument at the shore station, but on the mine being struck by a passing vessel the inertia weight *E* is displaced, causing the armature *c* to be pulled down in contact with *e*: this short circuits the signalling current through the fuze by the wires *w* and *w'*, but the current is of such a strength that it will not then fire the fuzes, though powerful enough to ring the signal bell, and drop the shutter in the instrument at the shore station; the latter operation automatically switching in the firing battery current, and exploding the mine, if this be desired. For "observation," or "at will" firing, the powerful current of the firing battery is sent through the bobbin wires of the electro-magnet, which brings the armature into contact with *e*, and so short circuits this current through the fuzes and fires them.

C.—The Fuze.

In any system of submarine mines the fuze is a vital function, for on its certainty of action the value of the mine altogether depends.

An electrical fuze being of necessity of more or less delicate construction, and as it may have to remain submerged in the mine for months, or even years where no ocular examination is possible, the greatest care is required in the designing, construction and testing of such a fuze.

For *mining* purposes generally three classes of electrical fuzes are employed, depending upon the nature of the work to be performed, and the nature of the firing current generator, but as for *submarine* mines the low tension, or platinum wire fuze is now universally employed, it alone will be considered.

Low tension fuzes have been proved by experience to be far superior to either high or medium tension fuzes for all the purposes of submarine mining.

They admit of individual tests at any time to determine their condition: they do not require to be fired by currents of high potential: they are free from danger of accidental ignition by the inductive action of currents in neighbouring conductors: and lastly they may be prepared to any required degree of sensitiveness to suit the particular work they are required to perform.

Necessary Conditions.—The following considerations as to the requirements of a perfect electrical fuze for submarine mining purposes are taken from a most exhaustive report on these fuzes by General Abbot of the Corps of Engineers, U.S.A., which forms a portion of the work of investigation on the part of the fortification board for developing a system of submarine mines for the defence of the harbours of the United States:—

1. The two insulated conductors required to convey the current should be flexible, tough, and of low electrical resistance.

Copper wires of good quality in size of No. 20 W. G. and of unequal length (5 inches and 7 inches respectively), best satisfy these requirements.

2. The insulation must be proof against deterioration from age, which is best fulfilled by a closely woven wrapping of cotton thread coated with paraffin, or with beeswax, resin, and tar boiled together.

3. The plug must be a non-conductor of electricity, not liable to deteriorate with time and exposure to damp air, nor to corrode the copper wires.

Beech wood, kiln dried and coated thickly on the outside wit[h] Japan wax, satisfies these conditions.

4. The shape of the plug must be such as to render any conta

between the wires impossible, and to clamp them so firmly that no accidental strain on the free ends can disturb their internal adjustment.

The conditions as to a perfect bridge will be separately treated of.

The submarine mining department of each country employs a low tension fuze of special construction, differing one from another in size, nature, and length of bridge, and method of forming the body, but the principle is the same for each one, and therefore the description of the following fuzes will suffice to explain this branch of submarine mining:—

1. The American service fuze.
2. The English service fuze.
3. The McEvoy fuze.

American Fuze.—The section of a fuze which according to General Abbot best fulfils these four conditions is shown in Pl. XI. at Fig. 1; the plug consists of three parts, viz., a cylinder *a*, an hollow cylindrical cap *b*, and a disc of paper *C*; the cylinder *a* is 0·25 inch in diameter, and 0·7 inch in length, grooved longitudinally on its opposite sides to receive the conducting wires *w*, *w'*, and entirely round the middle a cut 0·05 inch deep and 0·15 wide is formed: the wires with their wrappings of cotton are each pressed into one half of the longitudinal grooves until they reach the cut: they are then both bent sharply round to the left nearly at right angles, and are led through this cut until they have passed half round the cylinder *a*, when they are again bent at right angles and pressed into the other half of the longitudinal grooves. Thus each wire leaves the plug in the opposite groove from which it entered, and at no point can they come into contact with each other. The *inside* ends *d*, *d'*, are then bared, scraped, and cut to the proper length (about 0·1 of an inch), and prepared for the fixing on of the bridge: the hollow cylindrical cap *b* is formed with a strong shoulder at one end, leaving a smaller hole for the passage of the free ends of the conducting wires: this cap is made to closely fit the solid cylinder *a*, and the latter, smeared with glue, is forced into it until the end abuts firmly against the shoulder, leaving a small chamber round the inside ends of the wires *d*, *d*, to receive the priming *e*: *C* is a paper disc which closes this chamber, and is held in position by a drop of collodion.

The detonating composition *f* is contained in a cap *g*, made by punching a disc of stout sheet-copper into a cylinder form, fitting the plug *a* closely: the bottom is solid and contains 20 grains of detonating composition, which is held in place by a paper disc secured by a drop of collodion: this cap is 1 inch long, and 0·4 inch in diameter, and entirely encases the chamber of the plug, to which it is rigidly attached by applying a pressure at two opposite points near the top sufficient to indent them into the wood.

The fuze thus formed is 1·4 inches long, and 0·4 inch in diameter. As soon as completed, it is dipped into melted Japan wax, which supplies a uniform waterproof coating to the whole.

For submarine mining purposes a very sensitive fuze is not necessary or advisable, because its bridge should be capable of carrying without a dangerous rise of temperature the currents which must pass through it for the necessary work of testing, and for operating the circuit closer or automatic apparatus.

The current to operate the automatic apparatus, and for testing purposes, should not exceed 0·15 ampere and it has been proved by experiments that the rise of temperature at the bridge is nearly proportional to the square of the current, then taking 10 as the co-efficient of safety, General Abbot deduces the following formula for the firing current:

$$\sqrt{10 \times (0 \cdot 15)^2} = 0 \cdot 47 \text{ ampere.}$$

The Bridge.—The bridge *x* decided upon by General Abbot, after a series of very careful experiments with different metals and alloys of various lengths and thicknesses, is as follows: the metal is platinum alloyed with a certain percentage of iridium: the diameter of the wire is 0·0025 inch: the weight is 90 grains troy per yard: the length is $\frac{7}{22}$ of an inch: the electrical resistance is 3·25 ohms per inch. To attach the bridge to the inner ends of the conductors contained in the chamber of the plug the following method must be closely followed: the ends of the fuze wires must be slightly notched: well tinned: attached to the plug: and finally gauged to the exact length of the bridge: it is then easy with the aid of a spirit lamp to secure a perfect union of the two metals (the iridio-platinum of the bridge, and copper of the wires), and a uniform electrical resistance the bridge being secured, the ends of the fuze wires must be slightl bent towards each other, in order to relieve the bridge from ar

PL. XI

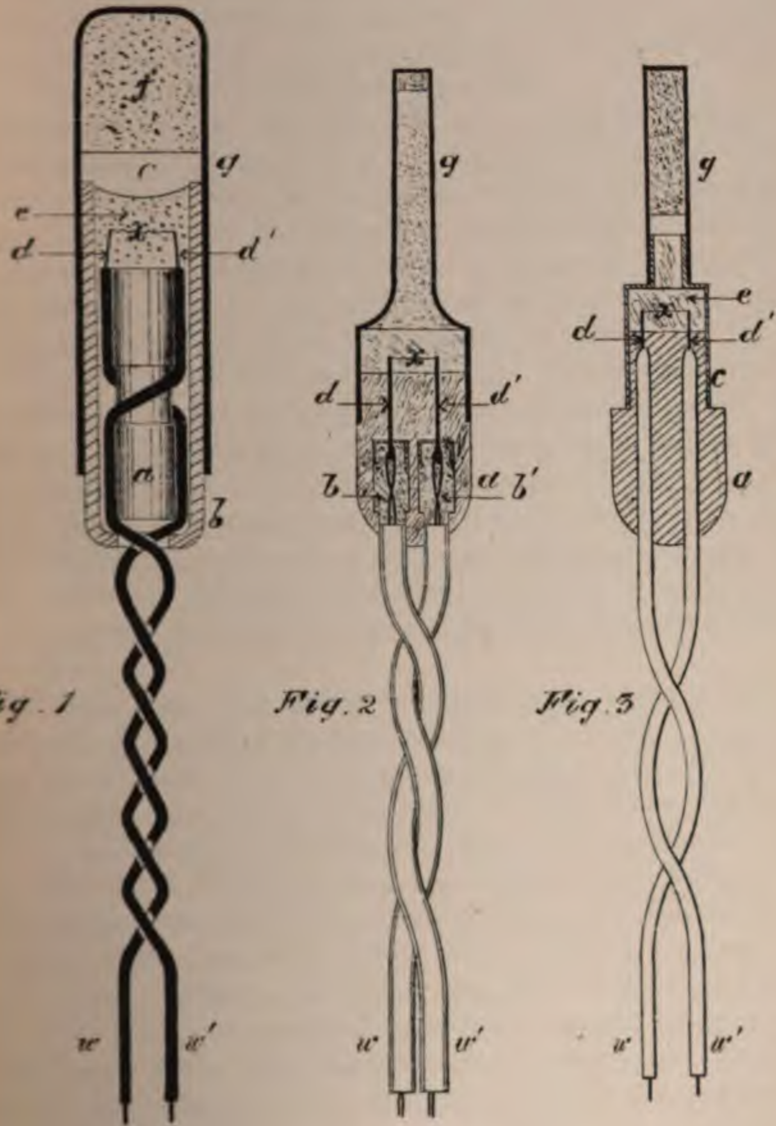


Fig. 1 Fig. 2 Fig. 3

possible strain even if the wood should change its form by warping or shrinking. The plug is then ready for insertion into the cap containing the priming, for which fulminate of mercury has been found by experience to be most suitable.

Permanency, uniformity, and ignition at a low temperature are the three essential requisites of a good priming, all of which are pre-eminently characteristic of fulminate of mercury.

English Service Fuze.—The platinum wire fuze adopted in the English service is shown in section in Pl. XI. at Fig. 2. It consists of a head of beech wood *a*, hollowed out, in which a metal mould *b* is fixed, the wires *w*, *w'*, which have been previously bared, are inserted into holes in this mould, and firmly fixed thereto by means of a composition poured in while hot: the two bared ends of the wires *d*, *d'* which project beyond the metal mould are connected by a bridge *x* of iridio-platinum wire (0·003" diam. and 0·25" long). This bridge is formed as follows: a very fine shallow groove is made in the flat ends of the bare wires *d*, *d'*, and the piece of iridio-platinum wire is laid across in these incisions and fixed there by means of solder. A tube *g* made of tin is soldered to a brass socket and fixed to the ebonite head, *a*, by means of cement: in this tube is placed the fulminate of mercury, the open end of this detonator being closed by a pellet of red lead and shellac varnish: around the bridge *x* of the fuze is placed some loose gun-cotton.

McEvoy's Fuze.—This form of low tension fuze is shown in Pl. XI. at Fig. 3. It consists of the head, *a*, formed of a mixture of ground glass and Portland cement, worked up with sulphur as a base: this mixture when hot is poured into a mould in which the two insulated wires *w*, *w'* have been previously laid: when cold the mixture with the wires affixed is removed from the mould, and the bridge *x* of iridio-platinum wire (0·002" diam. and 0·3" long), secured to the bared ends *d*, *d'* of the copper wires, and the whole is then firmly fixed in a brass socket *c* by means of cement: the space *e* is filled with loose dry gun-cotton, so as to surround the bridge *x*: a copper tube *g*, closed at one end, is partly filled with fulminate of mercury, and when the fuze is required for service this detonator is fixed to the brass socket *c* by means of cement.

In this form of low tension fuze there is no liability whatever of any injury being caused to the bridge by the working of the wires in the head, or by damp even after lying in the water for a month or more. One peculiarity of this fuze is that the composition is run over the insulated wires without materially softening the dielectric, or affecting in the slightest degree the insulation of the wires.

D.—THE CABLE.

The firing, the signalling, and the testing of controlled submarine mines is performed by means of currents of electricity conveyed to the mines by copper wires, which have to be very highly insulated, as they lay in the water, and armoured, as they rest on the bottom, where they would be subjected to continual and serious chafing. The insulated copper conducting wire is termed the "core," and when protected by armouring, &c., the whole is termed an "armoured cable" (electric): an insulated core when protected by outside sheathing, but not armoured, is termed a "cable" (electric): both kinds are designated by the number of insulated cores contained in them.

Different kinds of Cables.—A system of defence by controlled submarine mines requires the employment of the following cables :—

1. Single-core armoured cable.
2. Four-core armoured cable.
3. Seven-core armoured cable.
4. Single-core circuit closer armoured cable.
5. Single-core (telegraph) cable.
6. Four-core (observation) cable.

Qualifications of a perfect Cable.—The qualifications essential to a perfect electrical cable for use with submarine mines, are as follows :—

1. Capacity to bear a certain amount of strain without breaking.

2. Perfect insulation, or at least as nearly so as it is possible to obtain.

3. Capable of being readily stored, and kept for a considerable time without being injured, *i.e.* without any serious loss of insulation resistance.

4. Pliability, so that it may be wound on, or payed out from, a moderately-sized drum without injury.

5. Capability for resting on, or being dragged over, rocky or shingly bottoms, &c., without injury to the insulation.

Description of the Insulated Core.—Before describing the use and nature of the cables enumerated above, the nature of the insulated core, which is the same for all the cables except the special circuit closer one, will be explained, as contained in the English Government specification for submarine mine cables.

The conductor is composed of seven strands of tinned copper wires of best quality, *i.e.* its conductivity to be not less than 96 per cent. of that of pure copper at a temperature of 75° Fahr., the wire to weigh 93 lbs. per statute mile; this conductor is then insulated with three coats of india-rubber (of best quality) to a diameter of 0·24 inch; the insulation resistance to be not less than 1000 megohms, at a temperature of 75° Fahr.; this core is then taped with a spiral cotton tape coated with india-rubber: lastly the whole is then vulcanised together in a compact body.

Resistance of this conductor is 12 ohms per mile.

Single-core Armoured Cable.—This armoured cable is used for connecting each mine of a group to its junction box, or as the main cable in the "branch" system of mooring submarine mines.

The insulated core is first served with tarred jute, and then sheathed or armoured with ten best galvanised iron wires, No. 13 B. W. G.; each wire is covered with a spiral loop of prepared cotton tape while being passed through a bath of india-rubber composition; the whole cable is then served over all with two layers of tarred Russian hemp, and three coatings of preservative compound. A section of this cable is shown in Plate XII., Fig. 2. External diameter, 0·74 inch; breaking strain, 1·75 tons; weight per statute mile in water, 1·175 tons. This cable is supplied on drums in lengths of one mile.

Four-core Armoured Cable.—This armoured cable is more particularly intended for use between two observing stations when separated by water, but it may also be used as the main cable of a group of four mines.

In this case four of the insulated cores are stranded together, and the strand thus formed is served with tarred jute, and then taped over with prepared cotton tape: it is after this sheathed or armoured with 15 best galvanised iron wires, No. 11 B. W. G. (0·12 inch diam.):

each wire, while being passed through a bath of india-rubber, being coated with a spiral lap of prepared cotton tape: the whole is then served over all with two layers of tarred Russian hemp, and three coatings of preservative compound. A section of this cable is shown in Pl. XII. at Fig. 3, external diameter 1·07 inches: breaking strain 4·25 tons: weight per statute mile in water 2·16 tons. This cable is supplied on drums in lengths of one mile.

Seven-core Armoured Cable.—This armoured cable, usually designated "multiple" cable, is used for connecting the mine station on shore with the junction box of every group of 7 mines.

In this case seven of the insulated cores are stranded together, and the strand thus formed is covered and sheathed in the same manner as previously described for the four-core cable, with the exception that 16 best galvanised iron wires, No. 9 B. W. G. (0·148 inch diam.) instead of 15 wires of No. 11 B. W. G., as in the case of the four-core cable. A section of this cable is shown in Pl. XII. at Fig. 4, external diameter 1·35 inches: breaking strain 7·0 tons: weight per statute mile in water 3·78 tons. This cable is supplied on drums in lengths of one mile.

The nature of the protection provided for the foregoing cables is that which is described in the English Government specification for mine cables.

Circuit Closer Flexible Cable.—This single core flexible armoured cable is specially designed for connecting the circuit closer case with its buoyant or ground mine case in connection with the "combination" system, and for this purpose it needs to be most flexible, and yet of great strength. The single core cable described on page 57 was previously used for this purpose, but owing to the stiffness of its armouring it was often broken off at the circuit closer case, due to the considerable motion set up in the latter by the waves.

The cable about to be described has been designed and is constructed by the Silvertown Telegraph Works Co. The conductor is composed of 36 strands of No. 30 W. G. best galvanised iron wire: this conductor is then insulated by india-rubber, and by being taped with an india-rubber coated cotton tape: this insulated core is then braided over all with tanned jute, and sheathed or armoured with 7 strands of special steel wires: each strand is composed of 7 wire No. 20 W. G.: the whole is then coated with preservative compoun

SUB-MARINE MINE CABLES

PL XII

Fig. 1

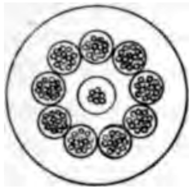


Fig. 2.

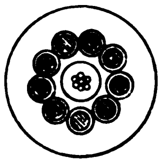


Fig. 3

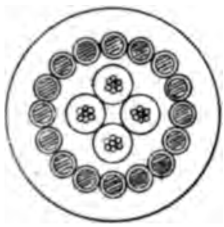
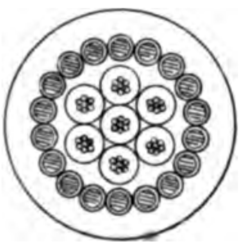


Fig. 4



& Co.

PORTSMOUTH

served with Russian hemp cords, and again compounded. A section of this cable is shown in Pl. XII. at Fig. 1, external diameter 0·785 inch: breaking strain 4·5 tons, or 2½ times more than for the ordinary single core armoured cable: weight per statute mile in water 1·125 tons. This cable is supplied on drums in lengths of 1,000 yards.

Single-core Cable.—This unarmoured cable is intended for connecting mine stations, forts, &c., together for telegraphic purposes, and is only to be laid underground. It consists of one insulated core, similar to that described on page 57, protected by a covering of tarred hemp.

External diameter 0·5 inch: breaking strain 9 cwts.: weight per statute mile in air 4·2 cwts.

Four-core Cable.—This unarmoured cable is used for the purpose of connecting (electrically) two observation stations when they are not separated by water.

It consists of a strand of 4 of the insulated cores before described, and is protected by a padding of hemp and two servings of tarred hemp laid spirally in opposite directions. External diameter 0·7 inch: breaking strain 0·9 ton: weight per statute mile in air 0·8 ton. For this service, where the occasion permits of the extra expense, it is always best to use the four-core armoured cable.

Special Cable.—For connecting the submarine mines attached to booms and other obstruction, the insulated core might form the core of an ordinary hemp hawser; when by reason of its appearance it might be readily mistaken for an ordinary rope, and so would most probably be cut by those attempting the removal of the obstruction: the effect of thus severing the electric core might, by previous arrangement, cause the explosion of the mines, or afford, by the interruption of the current, information to the defenders that the obstruction was being tampered with.

In forming the rope on the insulated core, great care must be exercised to prevent any serious amount of torsion, or tension being brought on the core, or otherwise its insulation might be damaged.

Preservation of Electrical Mine Cables.—A mine cable when stored dry should be most thoroughly dried beforehand; if stored in tanks it should always be kept under water, the temperature of which should never become excessive, nor should the cable be exposed to the direct rays of the sun, or any great degree of heat. The cable should not be coiled where it is possible to arrange otherwise; to avoid kinking, the cable should be reeled from one drum to another, and payed out from, and picked up on, a drum; on no account should the cable be thrown overboard in a coil or coils, and where this is unavoidable, as in countermining, the flexible armoured cable described on page 58 should be used.

Jointing Electrical Mine Cables.—The joining together of two *submarine* mine cables is a very important work, and great care must be exercised in its execution to secure perfect continuity, and perfect insulation of the circuit.

There are two kinds of joints, viz.:—

1. Permanent,
2. Extempore,

the latter being the kind generally resorted to in connection with the jointing of cables in a system of submarine defence, where the time and means for the use of the former are not generally to be obtained.

In both kinds of joints the following rules must be carefully adhered to:—

1. In laying bare the conductor, the insulation substance (dielectric) should be warmed and pulled off so as to prevent any chance of the conductor being damaged, as might occur were the dielectric to be *cut* off. If this rule cannot be observed, then every possible precaution must be taken not to nick the conductor in cutting off the dielectric.

2. The junction between the two conductors should be soldered, to secure perfect conductivity; where this work is not possible then every care must be taken to insure a perfect junction, *i.e.* the two conductors must be held firmly together.

3. The conductors before connection must be carefully cleaned, and the hands of the jointer must be dry.

4. Grease and dirt must be scrupulously avoided.

Permanent Joint.—The following methods and instructions for forming such joints are those adopted by Messrs. Siemens Brothers in connection with their telegraph cables, and will be found generally applicable to all insulated mine cables.

A joint consists of two parts, first, the connecting together of the two conductors; and second, the insulation of the connection.

The best method of joining together two conductors for a permanent joint is as follows:

The armouring, and the other protective coverings of the insulated core, is first removed and turned back some six inches, and then by the application of heat the dielectric is pulled off so as to bare the two conductors some three inches: if the dielectric be cut off, curved scissors should be used, and the cutting should be made in the direction of the conductor, never at right angles to it, for fear of injuring it.

Then clean the wires forming the strand with file-card and emery-paper, and solder them into a solid bar for a length of about one inch.

Having soldered the wires, forming the ends of the two lengths of conductors to be joined, into two solid rods, file each of them off in a slanting manner, so that they will form a scarf-joint when put together.

Place the two ends of strand in the two small vices on a stand which is supplied for the purpose, so that the two scarfed ends overlap each other, and bind them round with a piece of fine black iron wire, in the shape of a spiral, so as to keep the ends close together, then solder the two ends together by applying a hot soldering iron.

Then remove the iron binding wire and clean up the joint, filing off all unnecessary solder.

Next make a band of four fine tinned copper wires, and bind them tightly side by side round the joint, covering the whole length of the scarf, and then solder the band and joint solidly together.

Then make another band of four fine tinned copper wires and bind them round the joint in the same manner as before, but extending about a quarter of an inch beyond each end of the other binding wire, the parts only of this second binding which project beyond the end of the first binding are to be soldered, so that the centre part remains loose and may keep up a connection between the two ends by forming a spiral between them in the event of the scarf giving way and the two ends of the conductor separating slightly.

This form of joint is called the "spring" joint.

The finished joint should be washed with spirit of wine and brushed, so as to take away all particles of soldering flux, and to avoid oxidation of the wire. The washed joint should then be dried with a piece of cloth and exposed to the flame of a spirit lamp to dry it thoroughly. A cable conductor ought never to be jointed with the help of soldering acid, but with that of resin, sal ammoniac, or borax only, so that any chance oxidation, and consequently destruction, of the conducting wire may be avoided.

There are other modes of jointing conductors, such as the twisting and scale joint, but the foregoing method will sufficiently explain this part of electric cable work.

In an india-rubber insulated core the insulation of the connection between the two conductors is formed in the following manner: Clean the insulator with cloth moistened with mineral naphtha, so as to leave a clean adhesiveness only; taper the insulating material down to the conductor for about two inches on each side of the conductor-joint with a pair of curved and very clean scissors.

The tapering must be completed in such slanting way that the different layers of the dielectric are so far exposed as to enable a secure laying on of the new jointing material.

India-rubber core consists chiefly of three layers of insulating material: the first layer next to the strand is called the pure or brown; the second layer is the white or separating; the third layer is the light red or jacket rubber.

Coat the conductor with a pure (brown) rubber tape tightly laid on in a spiral form, commencing at the spot where the separator (white) ends, across the corresponding place on the opposite side of the joint and back again in a contrary direction. The ends are fastened down by pressing a clean, heated searing-iron or a heated knife on them. By doing so the band will stick; the remaining portions of the band to be cut off with the scissors.

Lay on tightly the separating india-rubber tape in the same manner, but beginning where the jacket or outer layer of rubber ends. One lap will be sufficient.

Complete the insulation by lapping on tightly two layers of red india-rubber tape: the last lap must cover each end of the core to four inches on each side of the conductor-joint, or extend to the searing, but not beyond it.

Lay on three tight bindings of the cloth tapes, all in the same direction, care being taken to avoid wrinkles. The ends of the cloth tapes are cemented down with a thin coating of india-rubber cement.

Immerse the joint in the jointing-bath at 150° to 200° F. and gradually raise the heat so that in half an hour the temperature will be 320° F., at which temperature keep the joint for twenty minutes: then take it out and let it cool in the open air.

In a Gutta-Percha Insulated Cable.—The following method is necessary: Clean and dry the joint well and cover the bare conductor with a thin layer of compound. This is best done by heating a small stick of compound to nearly its melting point, and rubbing it over the bare conductor, which has been previously heated with the flame of a spirit-lamp.

Heat the gutta-percha covering of both ends gently until it is quite soft, without, however, causing it to bubble or burn. Draw, then, with the fingers, the gutta-percha coverings of both ends down, tapering them off until they meet in the middle of the joint; heat them sufficiently to make them adhere together.

Apply a layer of compound on the tapered-off gutta-percha in the same manner as described for coating the bare conductor, and cover it with a first coating of gutta-percha sheet to about half the thickness necessary to finish the joint. This is done by heating a small sheet of gutta-percha, of about one-eighth of an inch in thickness, until it is quite soft, and by pressing it in that state round the joint to the required size; the greatest care to be taken to expel all the air.

The projecting lips are then cut off with a pair of curved scissors. The seam thus produced is to be rubbed with a hot iron until it is completely closed and the joint well rounded off.

Apply another layer of compound and a second layer of gutta-percha in exactly the same manner as described for the first layer; care, however, is to be taken to get the seam in this second layer of gutta-percha not over, but as nearly as possible right opposite to, the seam in the layer underneath.

The whole to be worked as cylindrical as possible, and to a size not exceeding the original core. The joint, so far finished, is then to be cooled with water until the gutta-percha is quite consolidated.

Another method: the overlapping gutta-percha joint, is made in the following manner:—

Cut off the two ends of the core, so that the gutta-percha and the conductor-wire are flush. Warm the gutta-percha for a distance of about three inches from each of the ends with the flame of a spirit lamp, and, when sufficiently soft, push it back until it forms an enlargement. The two ends of the conductor are then to be soldered according to instructions for making joints in conductors.

To have a perfectly clean surface of the two gutta-percha enlargements, remove all impurities by the way of peeling them with a sharp knife. Warm gently both knobs and the copper joint, and cover the whole length of the bare wire with compound, planing it with a warm smoothing-iron.

Draw then with the fingers one of the warmed and softened knobs carefully up to the other knob or enlargement, leaving on its way a perfect tube of gutta-percha upon the wire, decreasing gradually to the thickness of the copper strand towards the other knob. Any superfluous gutta-percha is removed. This scarf is finished with a warm smoothing-iron, so as to unite it to the compound on the wire strand, and a thin layer of compound is also put over the scarf in the same manner as before.

The other knob is then warmed and drawn in the same way over the tube already formed, which is at the same time heated sufficiently to make the two adhere.

Apply a layer of compound on the second scarf of gutta-percha, covering it in the same manner as described for coating the bare conductor, and cover it with a small sheet of gutta-percha in the same manner as described above, so as to make the finished joint to the size of the core as manufactured.

It will be apparent from the foregoing description of the formation of a permanent joint in a mine cable, that men specially trained in this work are required, as well as special tools and appliances, and considerable time, and as all these essentials will, as a rule, be difficult to obtain in submarine mining, the use of extempore joints will usually be obligatory.

Extempore or Temporary Joints.—Many species of extempore or temporary joints for both armoured and unarmoured cables have been from time to time devised, among which may be described the following as being the most practical, and the best known ones.

1. Tube joint.
2. Mathieson's joint.
3. McEvoy's joint.
4. McEvoy's armoured cable joint.

Tube Joint.—This form of joint is a very useful one for temporary

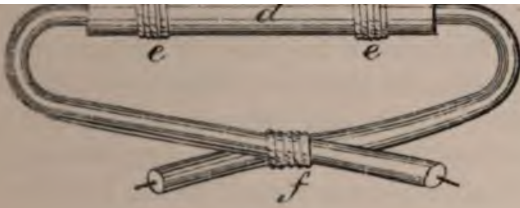


Fig. 3

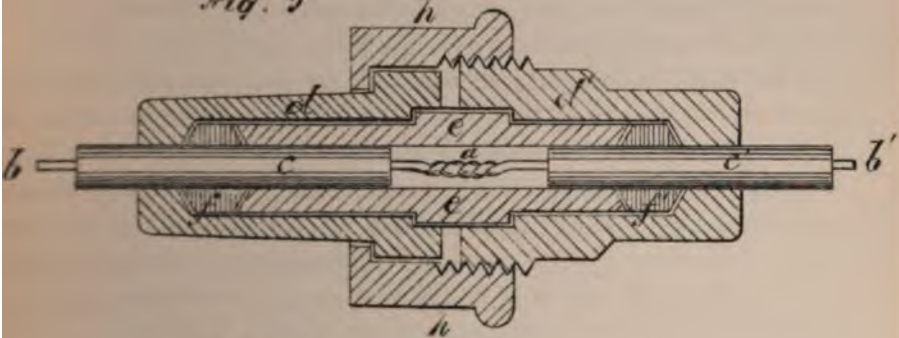


Fig. 4

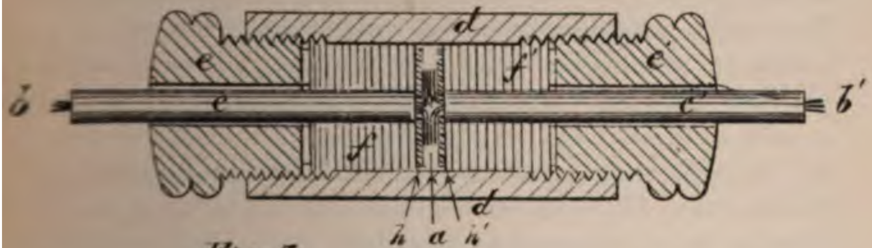


Fig. 5

purposes, as it is very easily and quickly formed, and yet is most effective if only due care be taken in its formation.

In Pl. XIII. at Figs. 1 and 2, a section and general view of this joint is shown, where *a* is the mechanical joint formed between the two conductors *b*, *b'*; *c*, *c'* is the dielectric; *d*, *d*, the india-rubber tube; *e*, *e*, the seizings; *f*, the half-crown seizing.

To make this joint, about two inches of the conductors *b*, *b'* are laid bare, cleaned, and twisted together, the ends being carefully pressed down by means of pliers, thus forming the joint *a*: previous to this connection of the two conductors being made, an india-rubber tube *d*, *d*, is drawn over the end of one of the cables, *c* for instance, sufficiently far to enable the joint *a* to be made, and then it is drawn back over this joint *a* and the other cable *c'*, and seized by twine *e*, *e*, to the two cables as shown in Fig. 1: a half-crown bend is then formed, the two parts of the cable being seized together as at *f*, Fig. 2, so as to bring any strain that may come on the cable on the seizing *f*, and not on the joint.

Mathieson's Joint.—This temporary joint was formerly used in the English service, but though it has now been superseded, it is described here as a great number of them are still in use, while it is very effective though somewhat complicated.

This joint, shown in section in Pl. XIII. at Fig. 3, consists of two ebonite cylinders *d*, and *d'*, an ebonite tube *e*, *e*, an outer ebonite nut *h*, *h*, and two vulcanite rings *f*, *f'*: the ends of the two cables *c*, *c* are first bared ready for jointing, and over the end *c*, the cylinder *d*, vulcanite ring *f*, tube *e*, *e*, and nut *h*, *h*, are slipped, while on the other end *c'* the cylinder *d'*, and vulcanite ring *f'* are placed: the joint *a* between the two conductors *b*, *b'* is then made: this being done the tube *h*, *h*, which has V-shaped ends, is then drawn over this joint *a*, and on to the cable *c'*: the other parts are then brought together, and the nut *h*, *h*, screwed tightly up. The centre of the tube *e*, *e*, is of square section, and fits into a hollow of similar section in the cylinders *d*, *d'*, so as to prevent any twisting of the wires during the process of screwing up, which might injure the joint *a*.

With this, and all other temporary or extempore joints, it is most advisable to form a half-crown bend in the cable with the joint in the crown.

McEvoy's Joint.—This McEvoy system of jointing affords a ready and most effective means of making the metallic joint between the two conductors, as well as of insulating it.

This joint, shown in section in Pl. XIII. at Fig. 4, consists of an ebonite cylinder *d, d*, two ebonite screw plugs *e, e'*, two discs of vulcanised india-rubber, *f, f'*, and two copper washers *h, h'*. The mode of making this joint is as follows: Half an inch of the two conductors is bared and cleaned: then over the core *c* is placed the plug *e*, cylinder *d*, and disc *f*: while over the other end *c'*, the plug *e'* and disc *f'* is placed: the bared ends of the two conductors are then turned back over the copper washers *h, h'*, respectively, and the metallic joint *a* is formed, and the necessary insulation and contact secured by screwing the two plugs *e, e'* into the cylinder *d, d*.

McEvoy's Armoured Cable Joint.—This method of connecting two armoured cables together is exceedingly simple, and most effective.

A section of this joint is shown in Pl. XIII. at Fig. 5, where *a* is the insulated metallic joint formed between the two conductors *b, b'*: *c, c'*, the two insulated cores: *d, d'*, the armouring of the two cables: *e, e*, a hollow brass body: *D, D*, an outer brass cylinder: *h, h'*, two brass screw plugs: *m, m'*, two thick brass washers. The mode of making this joint is as follows: The plugs *h, h'* are placed over the ends of the two cables *c, c'*, and the armouring is unlaid and bent back against their inner faces, as at *n, n'*: the washers *m, m'* are then placed over their respective cores *c, c'* against the bent back ends of the armouring: the external brass cylinder is slipped over the core *c*, and screwed into the plug *h*, and these are pushed back along the armoured cable *d* far enough to allow of the joint *a* being made: the body *e, e*, is then placed in position over this joint *a*, and between the two washers *m, m'*: the plug *h*, and cylinder *D, D*, are then brought forward over the body *e, e*, and the other plug *h'* is screwed into this cylinder: lastly, both plugs are screwed up tightly by spanners, firmly jamming the bent back armoured ends between the brass body *e, e*, the washers *m, m'*, and the plugs *h, h'*.

E.—The Junction Box.

When it is necessary to use a *multiple* cable, a junction box is used to facilitate the connection of the several separate cores of such a cable with those leading from a corresponding number of mines.

There are also required two kinds of *connecting* boxes, one in the shape of a T for connecting up the electro-contact mines on, what is termed, the branch system, and the other form is used for connecting together two multiple cables.

Seven-cored Multiple Cable Junction Box.—Plate XIV. shows different views of a junction box for one multiple, and seven single-cored cables, where Fig. 1 is the cover; Fig. 2, a plan; Fig. 3, the nipping hook; Fig. 4, an elevation; and Fig. 5, a section of the box.

The manner of using the junction box is as follows:—

The multiple cable is put in at *a*, Fig. 2, and secured in its place by means of a nipping hook, Fig. 3, which hook passes through the bottom of the box, and is set up by a nut: *b*, *b*, *b*, are the entrances for the seven single cores leading from the seven mines.

The seven cores of the multiple cable are respectively connected by insulated joints with the seven mine cables within the junction box, and each of these seven cables is held in its place by means of a nipping hook similar, but of smaller size, to that used for the multiple cable, and fastened in a similar manner. When all the connections are made, the lid, Fig. 1, is placed on and firmly secured by means of the screw eye-bolt *B* and nut *n*.

The nipping hooks are intended to take off from the joints any strain that may be brought on the cables, but as an additional precaution a Turk's head, or crown, is also formed on the multiple and each of the mine cables: one form of crown is shown in Fig. 8 at a, a', a'', which is made by turning back and serving over the armouring. The junction box is lowered to the ground by means of a ½-inch chain, or 2-inch wire rope secured to the eye-bolt, and at the other end to a buoy shaped as much like a buoyant mine as is possible.

McEvoy's Mechanical Turk's Head.—A far more neat and quick method of forming a Turk's head is McEvoy's mechanical one shown at Fig. 7, which consists of two brass collars *a* and *b*, the one *b* fitting and screwing into the other collar *a*: the armour wires of the cable *c* are turned back and cut to fit inside the collar *a* as at *d*, and the collar *b* is screwed up against this fringe of wires, and firmly jams them against the inside of the head of the collar *a*.

Connecting Box for Multiple Cable.—In Pl. XIV., Fig. 6, is shown a section of the box used for connecting two multiple cables together. This box consists of a pair of cast-iron boxes similar to the one shown at Fig. 6, which are bolted together at *a*, *a*: the grooves *b*, *b*, in which the multiple cables are laid are just large enough to firmly grip the armoured cables: the interior space is made large enough to hold the seven joints connecting the seven cores of the two cables: a crown is also formed on the multiple cable as explained for the junction box cables.

The connecting box, Fig. 6, may also be used for the four-cored multiple cable, but care must be taken to make the crowns of sufficient size.

T connecting Box.—The T connecting box is used with the system of electrical contact mines on branches from a single *main* cable.

This system is dependent on the use of a platinum wire fuze in the mine in connection with a platinum wire bridge, termed a "disconnector," or "cut out," placed in each connecting box in the circuit between the mine and main cable, as shown in Pl. XIV. at Fig. 8, which represents the section of a T connecting box with the cables *c*, *c'*, *c''* connected together, and the disconnector *d*: this box is made of cast-iron in two halves and bolted together.

Disconnector or Cut Out.—In a system where several mines are connected up to, and branch off from the same main cable, an apparatus must be placed in the circuit of each mine between its cable and the main cable, and of such a nature that on the explosion of one or more of these mines, it or they shall be at once disconnected, or cut out from the main circuit, or otherwise the mine or mines remaining unexploded could not be fired, as the current from the firing battery when put in circuit would short circuit through the broken (bared) end of the cable of the mine or mines exploded.

It will be seen that in any system where a number of submarine mines are branched off from a *single-cored main* cable the "cut out," or disconnector plays a very important part; for unless carefully and scientifically constructed it is possible for the "cut out" to destroy the efficiency of the system in two ways, firstly by acting *too soon*, *i.e.* cutting out the very mine it is desired to explode, secondly by failure to act, by which the remainder of the mines on this particular main cable could not be exploded.

PL. XIV

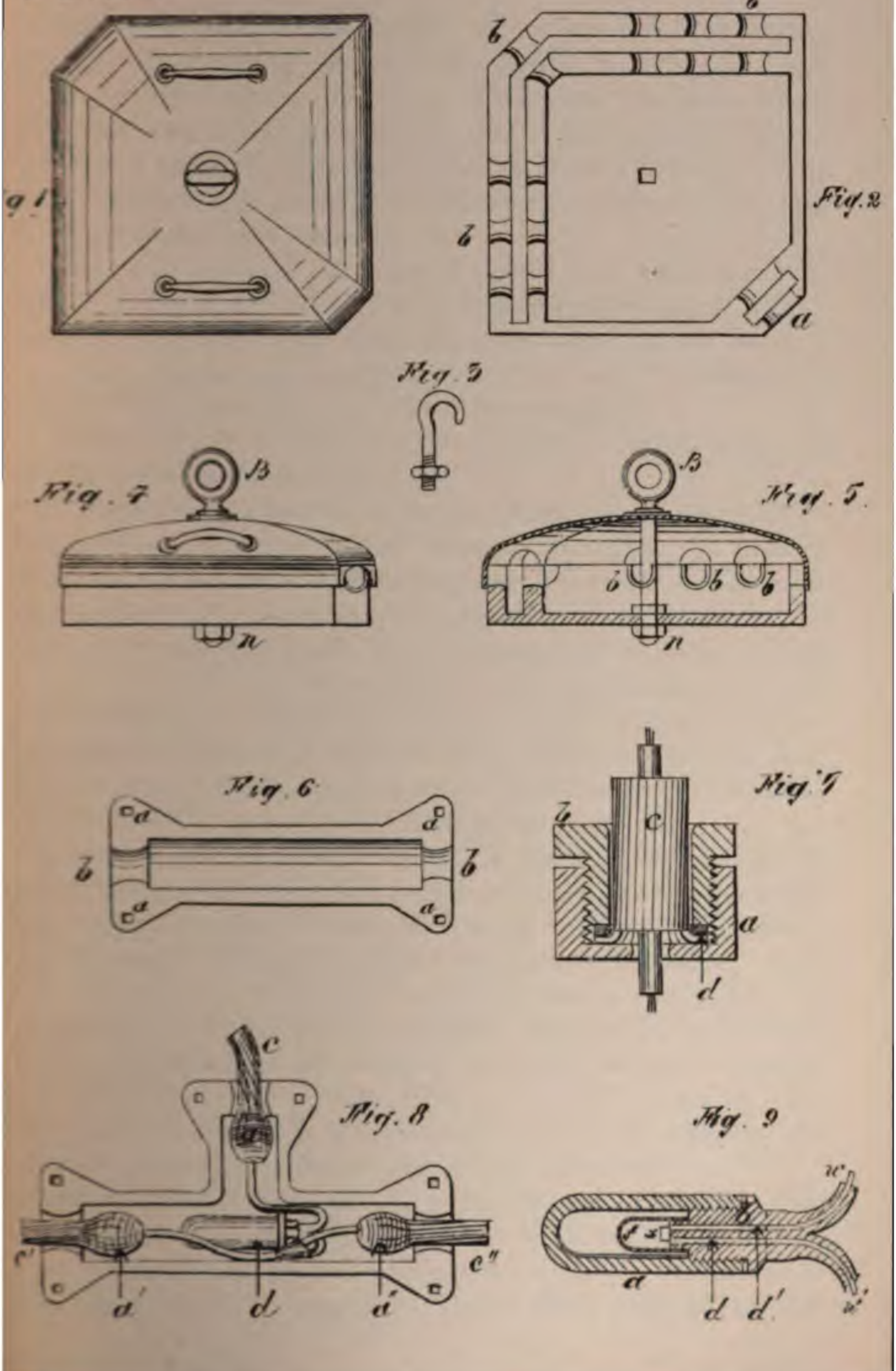


Fig. 1
b
b
Fig. 2
b
a
Fig. 3
Fig. 4
B
n
B
Fig. 5
b
b
b
n
Fig. 6
a
a
b
b
a
a
Fig. 7
b
c
a
d
c
Fig. 8
c'
c"
d'
d
d'
Fig. 9
w
b
a
d
d'
w'

The "cut outs" hitherto devised act on one of two principles: (1) the use of a firing current strong enough to deflagrate a fine platinum wire, similar to the bridge of the mine fuze, either simultaneously with the latter, or shortly after it has exploded: (2) the igniting of a wisp of gun-cotton attached to the fine wire of the "cut out," causing enough gas to be formed to remove a small wooden cap, and thus mechanically break the wire.

The consideration of the nature of a "cut out" which should insure its acting at the proper moment formed part of General Abbot's investigations on electrical fuzes, alluded to before, and the result of this part of his investigations proved that "cut outs" constructed on either of these principles were more or less unreliable.

General Abbot in describing his method of investigating this branch of electrical fuzes says:—

"Considered as a problem of heat and electricity, the best solution seemed to me to depend on the following principles. To produce simultaneous rupture at two different points of the same circuit, under the simplest conditions, these points should be physically similar, *i.e.* the cut off and fuze should have the same kind of bridge and the same kind of priming. When prepared with care the range of variation in these quantities may be made very slight; but since it cannot be absolutely eliminated, the influence of residual differences must be neutralised. Time is the only element under control which can be varied to effect this object. Experiment proves that when the minimum current required for igniting a fuze is passed through the bridge, the rise in temperature occurs gradually, and a very sensible time elapses before it becomes hot enough to ignite the priming; also, that as the current is increased this time is diminished. Even after the requisite temperature is reached, time is still required to perform the mechanical work of explosion. If, therefore, *by increasing the current within reasonable limits, the time needed to raise the temperature of the bridge to the requisite degree can be made less than the minimum required to perform the mechanical work of the explosion*, the problem admits of a satisfactory and certain conclusion."

A large number of experiments were carried out by General Abbot to prove that this theoretical result could be obtained in actual practice; two kinds of "cut out" fuzes were used, (1) the American service fuze described on page 53; (2) a fuze with a bridge of platinum silver wire, ¼ inch long, and 0·0015 in diameter; priming, fulminate of mercury; current to explode a single fuze 0·28 ampere; current to deflagrate the bridge 0·55 ampere.

The fuzes experimented upon were connected up in series, and the results proved that, "with fuzes primed with fulminate of mercury, a current somewhat less than three times the minimum required to explode a single fuze is sure to fire all in the circuit." The following table is a summary of these experiments.

With "cut out" similar to the American service fuze:

Currents varying from Amperes.	Per cent. fail.
0·8 to 1·0	50·
1·0 to 1·2	28·
1·2 to 1·3	8·
1·3 to 1·4	3·
1·4 to 1·5	1·
1·5 and more	0·

American Service Cut Out.—The American service "cut out" or "disconnector" then consists of a low tension fuze identical with their mine fuze, which has been described on page 53, except that the detonating cap is not required in a "cut out" fuze.

English Service "Disconnector."—In this "disconnector" the bridge is arranged to be deflagrated, but if the firing current should fail to effect this, it is provided with a mechanical means whereby its bridge will be broken. The disconnector bridge is made of platinum wire 0·4 inch long, 0·003 inch in diameter; while the bridge of the *mine* fuze is made of platinum wire 0·3 inch long; the object of this difference in length of the bridges of the mine fuze, and its disconnector is to ensure their simultaneous fusion.

An additional means of destroying the bridge of the disconnector is afforded by a small boxwood cover placed over the bridge with an ebonite pin passed through this cover below the bridge: in this cover some gun-cotton priming is placed in amount just sufficient to blow off the boxwood cover, and carrying the ebonite pin with it breaks through the platinum wire bridge. A section of this disconnector is shown in Pl. XIV., at Fig. 9, where *a* is an iron dome or cover which screws on to the ebonite body *b* of the apparatus, and which when screwed firmly down is made water-tight by a washer: *w*, *w'* are insulated wires, one of which is jointed to the branch or mine cable, and the other one to the main cable: *d*, *d'* are two copper conducting wires, No. 16 W. G., passing through the ebonite body *b* into the interior of the dome *a*: these wires are held together in the centre of the dome by means of a composition which also insulates them one from the other: *x* is the platinum wire bridge: *f* is the boxwood cover which fits on to the ebonite body *b*.

In connection with every kind of "cut out" it is most important to insure the case containing it being absolutely water-tight.

F. THE MOORINGS.

The efficient mooring of submarine mines is one of the most troublesome and most difficult functions of a system of harbour defence by such means, not only in the actual work of planting them in the exact positions assigned to them, but even more so in maintaining the mines in these positions for long periods of time under the ordinary adverse conditions of strong currents, or tides, rise and fall of the latter, and rough weather.

The essential points to be considered in mooring mines are:

a. Maintenance of position.
b. Retention of effective depth.
c. Prevention of injury to the electric mine cables.
d. Prevention of entanglement of two or more mines together.
e. Invisibility.

The three points, *c*, *d*, and *e*, are common to all classes of submarine mines, while the last one, "invisibility," together with the second one, "retention of effective depth," are the only ones that present any trouble in securing, and these only in places where the rise and fall of tide is exceptionally great, as for instance at Noel Bay, in the Bay of Fundy, where it is some fifty feet; thus contact mines planted here 20 feet below the surface, at high water, would at low water be visible and floating on the surface with 30 feet of slack mooring rope: while if moored so as to be just out of sight at low water, they would be some 50 feet below the surface at high water, and consequently useless as *contact* mines.

Many attempts have been made to overcome this trouble, but as yet no really practical method has been devised, and in fact the only way of overcoming this difficulty is the crude one of arranging the *lines* of mines so that the mines in one or more of the lines shall always be at the right depth below the surface of the water at every state of the tide: the outer mines being in right position at low water, and inner ones at high water, so that the latter, though exposed at low water, are yet protected by the outer ones, which would then be at their proper depth and invisible.

Ruck's System of Mooring.—The following is a brief description of the invention of Captain Ruck, R.E., for maintaining submarine mines or other floating bodies at a constant or nearly constant, depth below the surface of the water in places where there is a rise and fall of tide.

The anchor is provided with a pulley, and to the mine mooring rope a length of chain, graduated in size and weight, is attached passing through the pulley, and secured to a counterpoise: this counterpoise consists of either a metal case open at the bottom, or closed by a flexible waterproof diaphragm, or of a compressible waterproof bag completely closed, and properly weighted.

The principle of the invention is as follows:—

Supposing the time to be that of low water, as the water level rises, the pressure on the air in the counterpoise increases, more water therefore enters through the aperture at the bottom, or in the case of a collapsing bag the volume of air becomes smaller, hence the buoyancy of the counterpoise will decrease and it will sink: as it sinks however, the chain will pass round the pulley and the floating body will rise; a certain weight of chain will then be suspended from the floating body instead of from the counterpoise and a new position of equilibrium will then be taken up—another rise of water level will produce a similar result and thus the floating body will rise as the water level rises—as the water level falls, the inverse action takes place and the floating body falls whilst the counterpoise rises.

By calculating the weights of chain for every foot of rise of water level, the system can be so arranged that the floating body will maintain a constant depth below the surface whilst the water level fluctuates.

This arrangement might possibly prove effective in practice, but it appears to offer the risk of entanglement between the counterpoise and mine, and also the possibility of the chain becoming jammed in the pulley, which latter result would cause the mine to be either too deeply immersed, or to float on the surface at certain periods of the tide.

Maintenance of Position.—The first point, "maintenance of position," is an important one in relation to the mooring of mines intended to be fired by observation, in fact the effectiveness of such depends in a great measure on their being maintained in the exact positions assigned them, or otherwise they would either be fired too soon or too late, *i.e.* either before or after the hostile vessel had come on with the cross bearings, or again they might shift to the right or left of their normal position, which would materially reduce their destructive effectiveness, as this latter quality of a submarine mine is extremely local: for instance, a charge of 500 lbs. of gun-cotton exploded at its most effective depth beneath the surface of the water has a destructive radius of only some 31·7 feet.

As regards the comparative difficulties attendant on the planting of the different classes of submarine mines, the simple ground mine would present the least trouble were it not for the necessity of securing great accuracy of position, as it has to be fired by the observation method: the electro-contact mine may be considered as the most simple to moor, for though a mine and anchor has to be planted, yet as this class is fired by contact alone, it does not require to be moored so precisely exact in the position assigned to it: the class of mine offering the greatest trouble is the combination buoyant mine when intended to be fired by observation as well as by contact, as each one consists of an anchor, a mine case, and a circuit closer case, and besides great accuracy of position is essential.

Various methods have been devised for mooring submarine mines, but the most effective is the single steel wire mooring rope and the form of anchor illustrated in Pl. XV., as confirmed by many years' practical experience of submarine mining.

Different Systems of Mooring.—In Pl. XV. is shown the different systems of mooring submarine mines: Fig. 1 represents two electro-contact mines moored on the branch system on the same main cable *W*: *M, M* is the mine: *A, A* the anchor: *B, B* the wire mooring rope: *w, w* the mine cable: *T, T* the T connector box with disconnector. This mode of mooring has been devised to save the great cost of a multiple main cable, but it possesses the great defect of not providing for the separate testing of each mine, which is a desideratum overshadowing the saving represented by the difference in the cost of a multiple and single-core armoured cable.

It is more practical to place the seven disconnectors in one multiple junction box, instead of using the seven *T* connector boxes. In Chapter VII. this question is discussed at greater length.

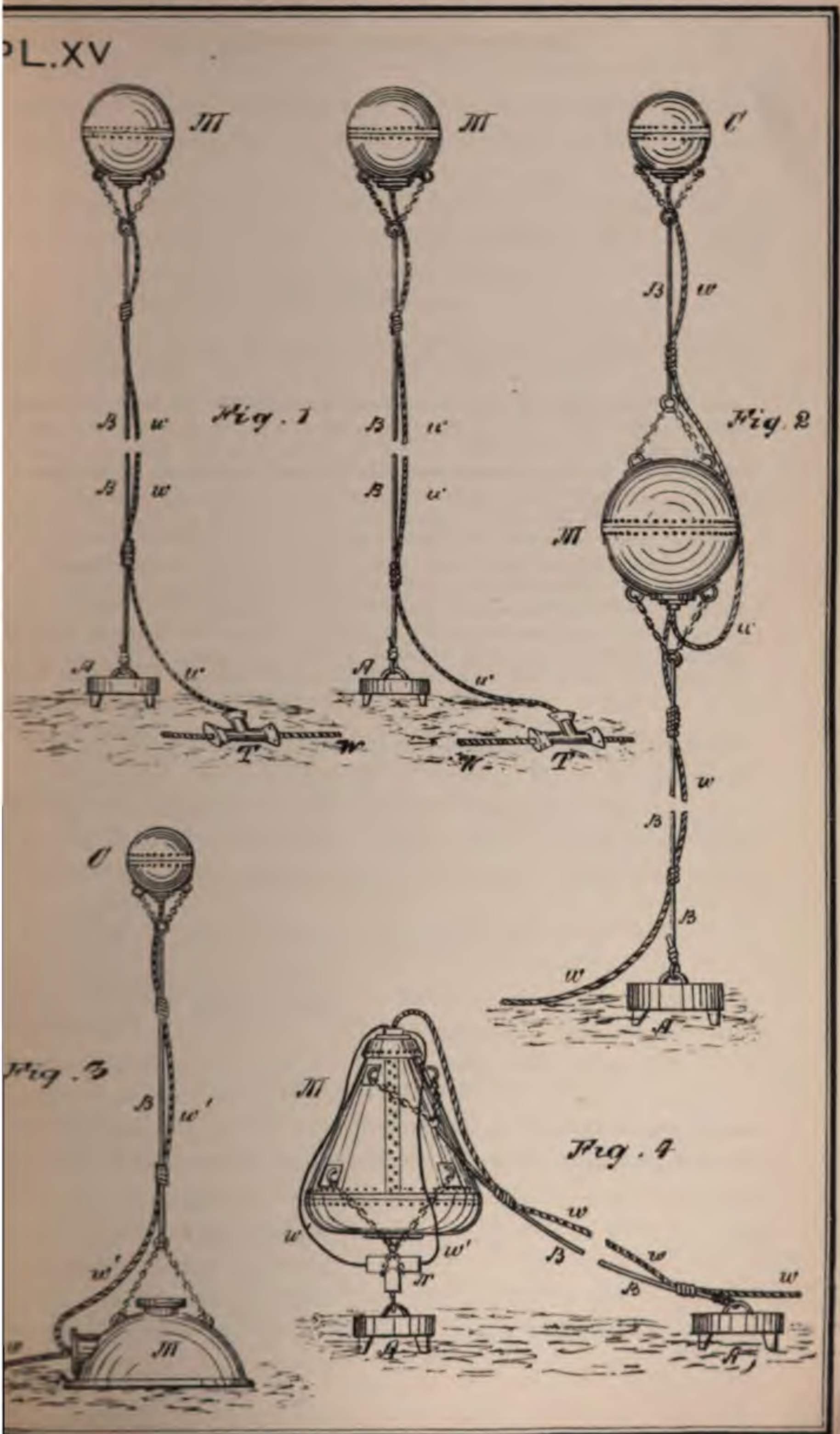
Fig. 2 represents a combination buoyant mine: *M* is the mine case: *C* the circuit closer case: *A* the anchor: *w* the mine cable leading to the junction box: *w'* the circuit closer cable: *B, B* wire mooring rope securing the mine case to the anchor, and the circuit closer case to the mine case respectively.

Fig. 3 represents the combination ground mine: *M* is the ground mine anchoring the system: *C* the circuit closer case: *w* the mine cable leading to the junction box: *w'* the circuit closer cable.

Fig. 4 represents a method of mooring electro-contact mines by which to prevent their being knocked about when laid down in peace-time, by the constant passing in and out of the harbour of friendly ships. *A* is the anchor maintaining the mine in its proper position when required for actual service: *A'* is the anchor holding the mine down close to the bottom by means of the explosive link *N*: *M* is the mine: *B, B* the wire mooring rope: *w* the mine cable: the mine is brought into its proper position whenever desired by exploding the link *N* through the wires *w'*, *w'*, which is effected from the mine station by means of either a second insulated core in the mine cable, or with a single-core cable by means of a relay in the mine.

Another plan of mooring submarine mines is that patented by Mr. Sydney Pitt, which has for its object the retaining of the mines, necessary to close the entrance of a harbour, in store until the moment of their being actually required. This is effected by arranging the mines on a chain cable equal in length to the distance across the mouth of the harbour, and then by means of pulleys on each side and hauling machines dragging this cable and the mines connected to it across the space to be defended. Practical demonstration alone can prove the feasibility of this scheme.

SUB-MARINE MINE MOORING.



CHAPTER IV.

GENERATING MACHINES AND ELECTRICAL MEASURING INSTRUMENTS.

A. Generating Apparatus—1. Frictional Machines—2. Voltaic Induction Machines—3. Magneto-electric Machines—4. Dynamo-electric Machines—5. The Laflin and Rand Machine—6. The Siemens Exploder—7. Voltaic Batteries—8. Firing Batteries—9. Single Fluid Chromic Acid Cell—10. Single Fluid Sulphuric Acid Cell—11. Leclanché Cell—12. Boat's Firing Battery—13. English Service-boat Firing Battery—14. Firing Battery for Self-acting Mines—15. Secondary Firing Battery—16. Signal and Testing Batteries—17. Sulphate of Copper Two-fluid Cell—18. The Watson Signal Battery—19. Minotti Testing Cell—20. Leclanché Signal and Testing Cells—21. Standard Cells—B. Measuring Instruments—22. Siemens Universal Galvanometer—23. Three-Coil Galvanometer—24. Detector Galvanometer—25. Thermo-Galvanometer—26. Direct Reading Ammeter and Voltmeter—27. Steel-yard Ammeter—28. Low Constant Voltmeter—29. Commutator—30. Firing Keys—31. Shunt—32. Rheostat—33. Resistance Box—34. Wheatstone Bridge—35. Measurement of Resistances—36. Telegraph Instruments.

A SYSTEM of defence by electrical self-acting and controlled mines necessitates the employment of various kinds of electrical measuring and directive instruments, and of apparatus for the generating of the electrical currents by which the fuzes of both these kinds of mines are fired, the electrical part of the system tested, and latter kind controlled.

These will be treated of under two heads, viz:

A. GENERATING APPARATUS.

B. MEASURING INSTRUMENTS.

A. GENERATING APPARATUS.

For the ignition of the fuzes of electrical controlled mines there are five kinds of generating apparatus which *may* be employed, viz.:—

1. Frictional machines.
2. Volta induction machines.
3. Magneto-electro machines.
4. Dynamo-electro machines.
5. Voltaic batteries.

The practice of submarine mining has proved most conclusively that for this particular work the ignition of fuzes is more suitably and conveniently secured by a voltaic battery of one kind or another than by any of the other machines enumerated above, except in very special instances where portability is an essential requirement, when some form of dynamo-electro machine becomes necessary; therefore only a brief consideration of the three machines coming first on the above list is necessary.

Frictional Machines.—Igniting machines of this class are similar in principle, and consist of a generator of frictional (high potential) electricity, a condenser to receive, store, and multiply the charge, and a key by which to direct the current through the fuze.

This class of machine requires the employment of fuzes of high or medium tension (which are not now used in submarine mining), and possesses the advantages of being capable of firing several such fuzes connected up in simple or direct circuit; of being able to perform this work even with a portion of the submerged leading wires bared to the water, and therefore its use does away with the necessity of very perfectly insulated wires; further it may be made lighter and more portable than any other kind of igniting machine possessing equal power.

It, however, possesses the following very serious disadvantages which, with voltaic batteries of the perfect type now to be obtained, entirely precludes its use for submarine mining purposes.

These disadvantages are: accidental injuries to the leading wires caused by the high potential nature of the current, thereby increasing the chances of missfires; the induction of the cables of mines lying near to the cable of the mine it is intended to fire, by which the fuzes of the former may be unintentionally ignited; that with these machines a charge of electricity cannot be retained for any considerable time without serious loss; that to generate a sufficient current charge at least half a minute is required, a portion of time which might nullify the effect of the explosion of a submarine mine for the reason that the ship to be destroyed by that mine may in even this short time have passed clear of it; lastly, in attempting to restore the charge it is possible to perforate the condenser by the over-estimating of the supposed loss of the charge. The following table gives some particulars of four frictional machines which have all been subjected to some very elaborate tests by General Abbot in his experiments and investigations on submarine mine material, with more or less success.

TABLE III.

TITLE.	Size.	Weight.	Length of Spark.	No. of turns of crank.
	inches.	lbs.	inches.	
Ebner (Austrian)	16 × 7 × 17	32	0·5	..
Smith (American)	14 × 14 × 7	26	2·5	25
Mowbray (American) . . .	19 × 14 × 13	42	1·0	60
Bernhardt (French) . . .	21 × 11 × 16	42	2·5	14

Voltaic Induction Machines.—This class of machine is constructed on the principle of the laws governing the inductive action of electrical currents upon neighbouring conductors.

A primary conductor in the form of a compact coil of many convolutions will produce, by means of a strong battery, an extra current of *great quantity* but of *low potential*.

If the primary coil be enveloped by a secondary coil, a secondary current of still greater power is produced either of high potential and low quantity, or the reverse depending upon whether the secondary coil be composed of long and fine, or of short and stout wire; these results being further intensified by enclosing a soft iron core within the helices.

Three machines were experimented upon by General Abbot, viz:

An extra current coil, a special induction coil, and an American "Service" induction coil, the latter of which far surpassed the others in suitability for submarine mining purposes.

The particulars of this service machine are as follows:—

Size . .	14 inches by 6 inches by 7 inches.
Weight . .	18 lbs.
Primary coil .	No. 14 B. W. G. Resist 0·1 ohm.
Secondary coil.	No. 35 B. W. G. „ 2·800 ohms.

A current of 4·5 amperes is required to give a continuous stream of sparks 1¼ inches in length, and this current was obtained from two large Grenet cells coupled in series.

A small 6-inch condenser, having a capacity of 0·0006 microfarad, was connected to the terminals of the secondary coil; this condenser increases the *density* of the spark, but diminishes its length.

With a well-insulated submerged conductor this machine is effective at a range of somewhat more than a mile.

Two fuzes are placed in the mine when using this machine; a low tension one in connection with the circuit closer for "automatic" firing, and which is ignited by the ordinary firing battery; and a medium tension fuze with a break of $\frac{1}{100}$th of an inch for firing "at will" by means of the induction coil. This break of $\frac{1}{100}$th inch was found necessary to prevent the simultaneous firing of other mines by induction. For this arrangement a double switch-key is provided, which in one position closes the primary circuit, and in the other puts the ordinary firing battery in circuit; thus igniting the mine "at will," whether the circuit at the mine be opened or closed.

Magneto-Electro Machines.—The principle upon which magneto-electro machines, *i.e.* apparatus for the generation of electrical currents by magnetism, depends is precisely similar to the voltaic induction machine which has been previously described.

A magnet inserted by successive movements into a continuous ring of wire will induce, in that ring, an instantaneous current of electricity; while withdrawing the magnet in the same manner will also cause a current, but in the opposite direction.

Looking at the ring *from the side on which the magnet is inserted or withdrawn*, then

N	pole	inserted,	direction	of	current	against	hands	of watch.
N	„	withdrawn,	„	„	„	with	„	„
S	„	inserted	„	„	„	„	„	„
S	„	withdrawn	„	„	„	against	„	„

Replacing the ring of wire by a spiral coil the direction of the current will remain as above, but the potential will be increased.

Or a similar effect is produced if the magnet be fixed, and a soft piece of unmagnetized iron inserted in the coil be successively magnetized and demagnetized by rapid contacts with the magnet.

Again, if the poles of a permanent magnet be extended by soft iron rods enveloped by coils of wire and the armature be applied or withdrawn suddenly a similar effect is produced.

All magneto-electro machines are based on these principles, as differ simply on the mechanical devices used for effecting the magnetic changes in, or near a coil of insulated wire.

There are three classes of magneto-electro igniting machines, viz.: I. Those acting by single electric wave; II. those acting by a succession of waves alternating in direction; III. those acting by a continuous current.

The latter class includes those of Class II. when commutators are used.

General Abbot carried out some very careful tests with a number of machines representing each of these classes, the results of which are given in the following Table:—

TABLE IV.

Class.	Name.	Box. Size. Inches.	Box. Weight in lbs.	Coils. No.	Coils. Resist ohms.	Fuze.	Remarks.
I.	Breguet	18×7×6	21	2	9,400	Medium tension	Formerly used in the Swedish naval service.
I.	Jurgensen	12×6×4	16	2	1,170	"	Formerly employed in the Danish naval service.
I.	Marcus	5×4×13	20	1	280	"	Austrian and Prussian land service. French naval service.
II.	Wheatstone	12×11×12	58	24	8,400	"	
II.	Beardslee	18×18×14	115	10	1,100	"	Used with great success during the American Civil War.
III.	Gramme	14×13×25	67	30	0·65	Low tension.	

For the low tension (platino-iridium wire) fuze now in general use for submarine mines the Gramme machine is the most simple and perfect magneto-electro machine, as it eliminates the troublesome commutator required with the machines of Class II. when these fuzes are employed, and it supplies a current as uniform as that of the best voltaic battery.

Dynamo-Electro Machines.—This class of machine differs from the magneto-electro machine only in the use of *electro*-magnets in the place of *permanent* magnets.

In dynamo-electro machines there is no liability of deterioration from the gradual loss of permanent magnetism, and with equal weight they can be made more powerful; but they require more physical force to manipulate them.

Dynamo-electro igniting machines may be divided into three classes, as follows:—

I. Acting by a diminishing wave . . .	Siemens' Spark, Farmer, Smith, Laflin and Rand.
II. Acting by a succession of waves, alternating in direction	Ladd, without commutator.
III. Acting by a continuous current . . .	Siemens' Current, Ladd with commutator, Hochhausen Gramme.

These machines are compared together in Table V.:—

Name.	Size.	Weight.	Remarks.
	inches.	lbs.	
Siemens' Spark .	14 × 7 × 13	52	One turn of crank gives 6 turns of armature. One Abel fuze fired through 2 miles—submerged circuit—earth return; or 12 fuzes in series on short land service.
Farmer . . .	13 × 11 × 18	120	One turn of crank gives 7·3 turns of armature. For 1000 revolutions E.M.F. for an instant 30 volts—continuous 20 volts. Adopted in U. S. naval service.
Smith . . .	13 × 10 × 15	77	One turn of crank gives 6 turns of armature. For 1,044 revolutions E.M.F. 11·55 volts. One fuze fired through 20 ohms resistance.
Laflin and Rand	16 × 8 × 5	18½	This machine is described in detail.
Ladd. . . .	22 × 14 × 23	119	One turn of crank gives 155 turns of armature. At 1,000 revolutions E.M.F. 7·5 volts. One fuze fired through 14 ohms resistance.
Siemens' Current	9 × 7 × 12	32	One turn of crank gives 10·8 turns of the armature. One fuze fired through 13 ohms resistance. A very neat and portable machine.
Hochhausen. .	12 × 11 × 12	84	One turn of crank gives 3·2 turns of the armature. At 425 revolutions one fuze fired through 15 ohms resistance. At 700 revolutions one fuze fired through 30 ohms resistance.

The Laflin and Rand Machine.—This machine, known as "Magneto No. 3," was patented in 1878. It is a most portable and convenient instrument, as it occupies only 0·37 cubic foot, and weighs only some 19 lbs.

This machine is illustrated in Pl. XVI., where Fig. 1 is a general view: Fig. 2 a side view: Fig. 3 an end view: and Fig. 4 a plan of the connections.

It is constructed on the Wheatstone and Siemens principle, *i.e.* a Siemens armature revolving between the poles of an electro-magnet of horseshoe form.

DYNAMO — ELECTRO EXPLODER.

PL. XVI

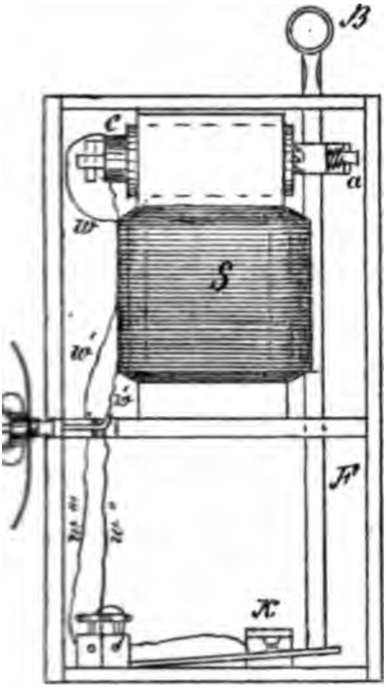


Fig. 2

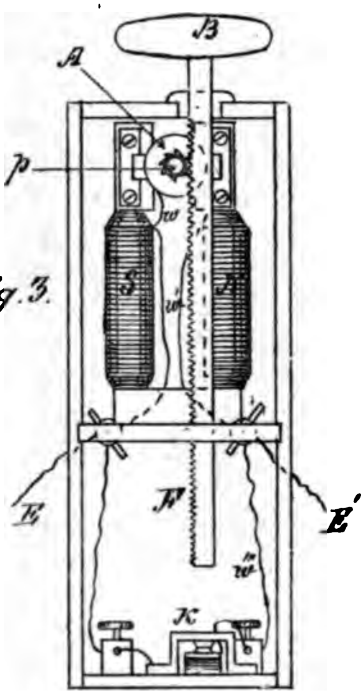


Fig. 3.

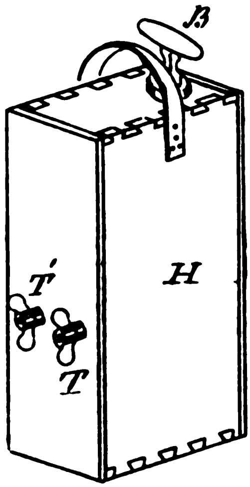


Fig. 1

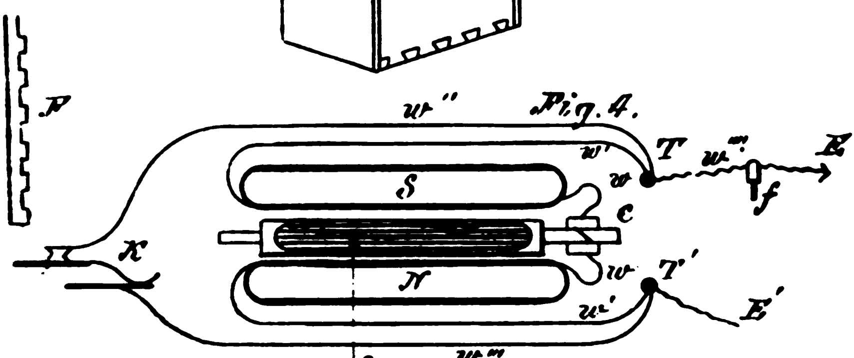


Fig. 4.

The electrical alternating currents thus formed are transformed by means of a commutator into one continuous current.

The circuits will be readily understood from the diagram figure 4: *A* is the armature revolving between the poles of the magnets *N*, *S*: *T*, *T'*, the two terminals to which the fuze circuit wires are connected: *C* is the commutator, *K* a spring contact key: *F* the firing bar. The circuit passes from the commutator into the magnet windings by the wires *w*, *w*, and out by the wires *w'*, *w'*, to the terminals *T*, *T'*, thence by the wires *w''*, *w'''*, to the platinum contacts of the spring key *K*, thus completing an interior short circuit tapped by the fuze circuit as a shunt: this fuze circuit is represented by the cable *w''''* leading from terminal *T* to the fuze *f*, its earth wire *E*, and the machine earth wire *E'*.

The magnet is wound with cotton insulated copper wire, No. 18 B. W. G., with a total resistance of 1·76 ohms, and the armature with No. 21 B. W. G. with a total resistance of 0·92 ohm.

The novelty of this machine lies in the mode adopted for the rotation of the Siemens armature, and of switching into the fuze circuit the powerful internal current thus induced.

Both these objects are accomplished by means of the firing bar *F*, which consists of a square brass rod 14" × ½" × ½", fitted with a wooden handle *B*, Figs. 1, 2, and 3, on its outer end: one side of it is provided with rack teeth engaging in a loose pinion *p*, Fig. 3, fitting over the armature spindle *a*, Fig. 2: a clutch holds this pinion to the armature spindle only on the *downward* stroke of the firing bar, so that the armature is revolved in one direction only.

In using this machine the firing bar *F* must be raised to its full length by the wooden handle *B*, and then pressed down with moderate speed for the first inch of its stroke, and finishing with a rapid motion: the shock of the bar striking the key *K* breaks the circuit between the two platinum contacts of this key *K*, and thus shunts the current into the fuze circuit: in passing from the top to the bottom of the box the firing bar *F* causes 7½ turns of the armature *A*, and if the movement be the result of a sudden and strong downward pressure a powerful current is developed.

This machine is capable of firing a single fuze (which requires a current of 0·45 ampere) through about 30 ohms: or 8 fuzes in series on short circuit: or 5 adjacent guns simultaneously, allowing 2·5 ohms for the resistance of the leading wires.

General Abbott's general working equation for this machine is

$$C = \frac{15\cdot^{v}}{2\cdot\overset{\omega}{7} + R_u}, \text{ where}$$

C is the current in amperes: 15^{v} is the measured *E. M. F.*: $2\cdot7^{\omega}$ the resistance of the machine; and R_u the resistance of the external circuit.

The points requiring attention in this machine are that no dirt be allowed to collect between the platinum contacts of the key *K*: that no metallic dust bridge the cuts in the commutator: and that the bearings be occasionally oiled.

The box *H*, Fig. 1, may be readily opened for these objects by removing a few screws.

Siemens Exploder.—Two types of this machine are constructed by Messrs. Siemens Brothers, both of which are shown in elevation in Pl. XVII., Figs. 1 and 2, the former being fitted with a multiple armature, and the latter (English War Office pattern) with a T armature, both being fitted with an automatic firing arrangement.

The machine shown at Fig. 1 is constructed as follows: the firing mechanism consists of a small toothed wheel, which is fixed on the driving spindle and gears into a wheel bearing a cam; the cam acts on a double spring so arranged that during two turns of the driving handle the machine is short circuited, but at the third and fourth turns one side of the spring is lifted from the short circuit contact, whilst the other side closes the line circuit. To show the proper time for connecting up the main wires, a signalling arrangement is provided which consists of a hammer and spring: a pin on the beforementioned cam presses against the spring and causes the hammer to strike the wooden cover of the machine when the driving handle has been turned the proper number of times.

One turn of the handle gives six turns of the armature. The weight of this machine is 70 lbs.: its dimensions about 15″ × 15″ × 7″.

The machine shown at Fig. 2 is fitted with two handles and a fly-wheel so as to insure a greater and more uniform speed of th

PL. XVII

Fig. 1

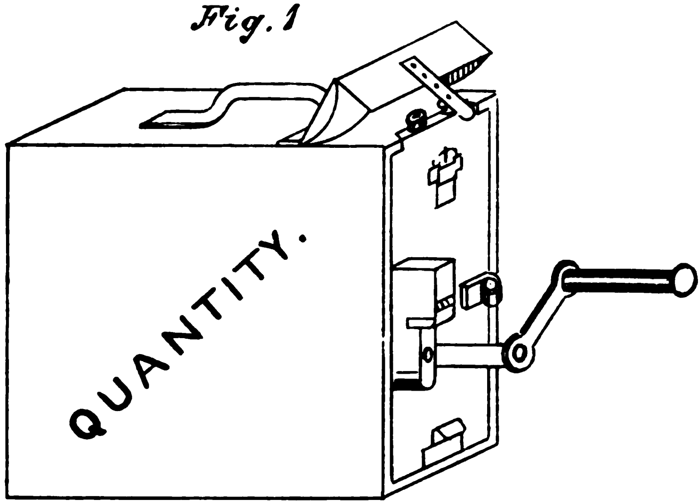
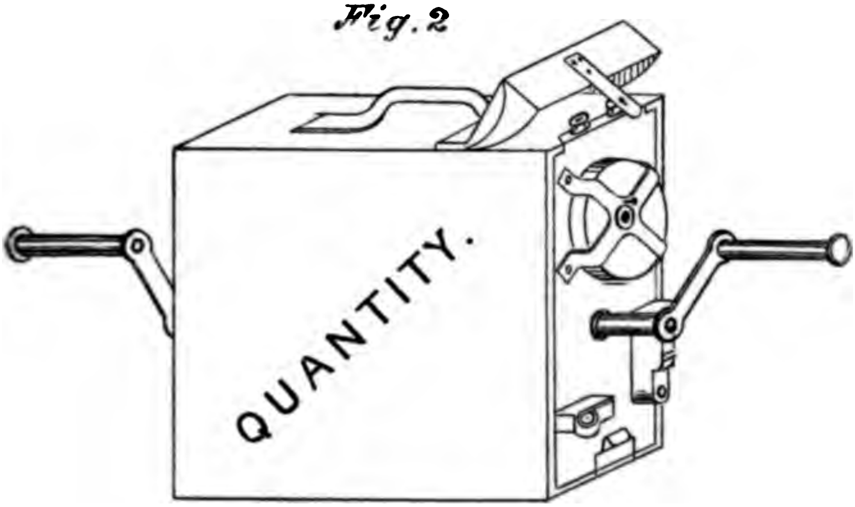


Fig. 2



armature. The signalling arrangement consists of a bell, the clapper of which is actuated in the same manner as the hammer in the machine before described.

One turn of the handle gives six turns of the armature. Weight of this machine 75 lbs.: its dimensions about 17″ × 15″ × 7″.

Either of these machines is capable of fusing a piece of iridio-platinum wire 0·0015 inch in diameter, through a resistance of 70 ohms, or a piece of same length but 0·003 inch in diameter through 20 ohms.

With 70 ohms in circuit the current of each machine is approximately 0·19 ampere, with an E. M. F. of 15 volts.

Voltaic Batteries.—Submarine mines must always be capable of being exploded by automatic means, as for instance at night time, and in thick, or foggy weather an enemy's vessel attempting to pass a line of mines would most probably be undiscovered by the defenders until too late; thus if in attempting to execute this service the hostile ship should strike a mine, the latter must be capable of being exploded automatically at the moment of the shock, or otherwise she would probably pass through in safety.

This fact necessitates the firing battery being such that it possesses a potential energy ready for instantaneous use, and which can be automatically switched into the fuze circuit of the mine that is struck by the attacking vessel.

On account of these conditions some one kind or other of voltaic battery is the most suitable form of firing battery for submarine mines, as in the case of the igniting machines previously described, an expenditure of mechanical power is required to develop the potential energy needed for the ignition of the mine fuze, and at the same time the explosion of the mine by these means can only be determined by an intelligent agent; at night time, or in thick or foggy weather, this agent would not be in a position to ascertain, a sufficient time in advance, the approach of an enemy's ship even by the aid of the electric light; while the fact of the hostile ship having struck a mine being signalled to the intelligent agent by the ringing of its particular bell would not permit of the agent exploding the mine actually under or in contact with the ship, owing to the time that must elapse before the mechanical power necessary to develop the needful current can be brought into play, by which time the hostile ship would probably have succeeded in passing beyond the dangerous zone of the explosion.

As General Abbot remarks, "Human agency and human fallibility are thus (by the use of voltaic batteries) in a measure eliminated."

In the submarine mine service, voltaic batteries are required for the performance of five functions, viz.:

1. Firing Batteries.
2. Signalling Batteries.
3. Testing Batteries.
4. Telegraph Batteries.
5. Electric Light Batteries.

Each of these will be considered separately, though in the case of the first four functions the Leclanché type of voltaic battery has been found capable of fulfilling all the necessary conditions.

Firing Batteries.—The qualifications of a firing battery are high electro-motive force with low internal resistance so that a strong current may be sent through a long length of cable: constancy is not needed as the action is instantaneous: while for all classes of batteries simplicity of construction, and easy access to the parts of the various cells for the purposes of cleaning are most essential.

The varieties of voltaic batteries that are more or less suitable as firing batteries are very numerous, and they differ among themselves in electro-motive force, in internal resistance, and in constancy of action; it will however be unnecessary to do more than briefly describe those voltaic batteries which have been used for the purposes of igniting the fuzes of submarine mines, but which have now been almost entirely replaced by the Leclanché firing battery, of which a full detailed description will be given.

Single Fluid Chromic Acid Cell.—A battery of fifty of these cells has been occasionally used for the firing of submarine mines by the American military authorities at Willett's Point.

A description of this and the other firing batteries that follow has been extracted from General Abbot's well-known Report on Submarine Mines, which contains a most exhaustive account of his experimental researches on all kinds and forms of voltaic batteries for submarine mine work.

This firing battery was composed of fifty of these chromic acid cells connected up in series: each cell consisted of a plate of carbon and of zinc immersed in the chromic acid contained in an insulated lead-box when required for use: each plate measured 9″ × 4½″, and was submerged 6½″ × 4½″: the plates were placed ½ inch apart.

The electrolyte was formed as follows: to 1 gallon of boiling water add 6 lbs. of potassium bichromate: stir for 15 minutes, then add 4 gallons of cold water and 1 gallon of sulphuric acid of commerce: stir the whole occasionally until all the bichromate crystals are dissolved.

The action of the bichromate acid on zinc is so intense that it is necessary to arrange the plates to be immersed only at the moment of firing, and this was arranged to be executed automatically in the following manner: all the plates of the battery were rigidly attached to a frame supported over the cells by a counterpoised walking beam, and the plates were plunged in and raised out of the electrolyte by means of an electro-magnet by the aid of a separate small battery: this operation was effected either automatically on a mine being struck, or at the will of the operator. The E. M. F. of each cell was 2 volts, and the internal resistance 0·2 ohm. The battery was capable of firing a single fuze through a resistance of some 190 ohms: or for two or more fuzes coupled in series through a resistance of 56 ohms, or about 4 miles of mine cable.

The Single Fluid Sulphuric Acid Cell.—This type of voltaic cell was originally devised by "Smee," and was in the early days of submarine mining adopted by the torpedo authorities in England and Austria for the firing of submarine mines, and were known respectively as the "Walker," and "Von Ebner" firing batteries.

The positive element is zinc always kept immersed in a cup of mercury: the negative element is carbon, either coke or graphite. The Walker cell consists of two graphite plates with a single zinc plate between them: while the Von Ebner cell has two zinc plates with a single graphite plate between them.

The following is a description of a firing battery of these cells as devised by General Abbot after careful experiment at the American torpedo school at Willett's Point: only one zinc and one coke plate is used: the former measuring 4½″ × 9½″, the latter 5″ by 9″, each giving a submerged surface of some 30 square inches: the zinc plate stands in a small cup of india-rubber containing mercury to preserve the amalgamation. These elements are placed in a glass jar, holding about 2½ quarts of the electrolyte, which consists of dilute sulphuric acid, one part to fourteen by volume: the top of the jar for about 2 inches is smeared with paraffin oil to prevent the creeping up of the acid.

The two plates are attached together by two ebonite rods, passing through holes made for the purpose, and are kept apart by ½ inch ebonite washers on the rods between the plates, which are clamped together by ebonite nuts screwed on to the outer end of the two ebonite rods: both rods are below the fluid, one being placed near the top, and the other near the bottom of the plates. A metallic connection is made in the top of the coke plate by two silver wires sewed through it and attached to a small copper bar: the zinc plate is provided with a copper terminal: all the connections are painted with asphaltum varnish: the top of the coke plate, for about 3 inches, is smeared in melted paraffin to close the pores, and to prevent the creeping up of the acid: the zinc plate, for about 2 inches, is painted with asphaltum varnish.

The cells are coupled together by stout copper wires screwed into the copper bars of the coke plates, and connected to the copper terminals of the zinc plates by screw cups.

To secure the necessary insulation the cells are placed on paraffined dry strips of wood nailed upon shelves.

It has been found by experience that a battery of this kind does not need renewal oftener than once in a couple of years, provided that care be taken to renew the water lost by evaporation, and to occasionally remove any zinc sulphate that may be formed.

A firing battery should consist of not less than 100 such cells, and it may then safely be considered effective at a range of one and a half miles.

The E. M. F. of this cell is 1·2 volts, but owing to its rapid polarization not more than 1·0 volt should be allowed: the internal resistance is about 0·3 ohm.

All varieties of the "Smee" cell have one common fault, low electromotive force: but the cell has the merits of simplicity, of yielding a very steady current when the polarization has reached its limit, and when properly set up, of preserving its efficiency without attention for long periods of time.

PL. XVIII

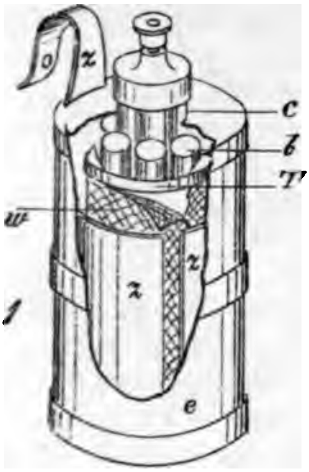
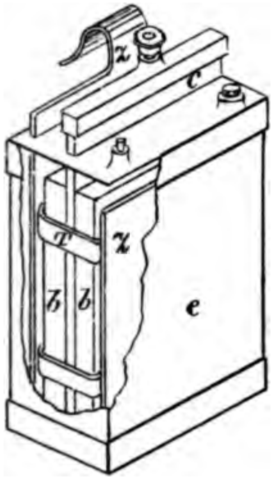


Fig. 1



z

Fig. 2

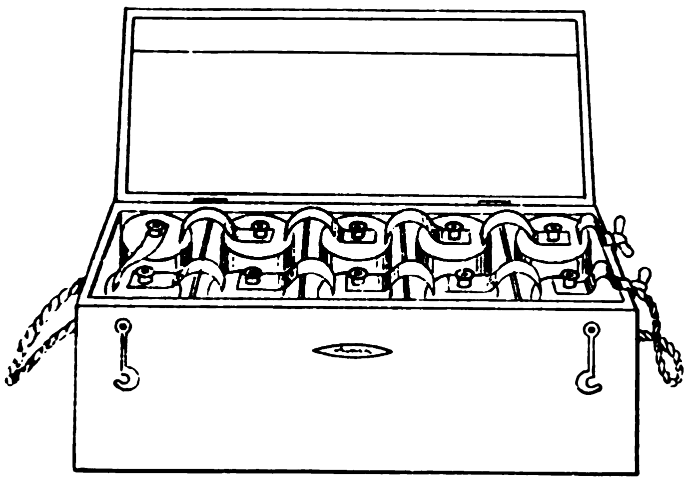


Fig. 3

Leclanché Cell.—Firing batteries composed of this type of sal-ammoniac cell are now universally used in connection with submarine mine work, as it possesses the essential quality of such a battery, that must be always ready for action, viz.: No local action on open circuit: while it possesses the further useful elements of a comparatively high E.M.F. and a low internal resistance. A battery of 100 Leclanché cells of the old type was set up by General Abbot at Willett's Point in 1874, and remained in constant use as a firing battery for a space of six years: the E. M. F. remained during this long period of work essentially constant, but the internal resistance gradually increased, this latter quantity could, however, have been brought to the standard of 0·3 ohm by adding water: but to avoid any overflow or creeping up of the salts this was not done.

The following is a description of latest type of Leclanché firing as constructed at the Silvertown Telegraph Works.

Two types of the improved Leclanché cell are in use, viz., the cylindrical, and the rectangular shape.

In Pl. XVIII. at Fig. 1 an illustration of the *cylindrical* type is given, showing the internal arrangements of the cell.

The positive electrode consists of a fluted carbon (graphite) rod *c*, and six agglomerate rods *b*, composed of equal proportions of binoxide of manganese and graphite, surrounding the centre rod *c*: the grooves in the latter are of little less diameter than that of the rods *b*: the six rods are held in close contact with the centre rod *c* by india-rubber bands *T*, so that the small spaces between the two facilitates the circulation of the liquid, and the dissipation of the evolved gas: the negative electrode is a cylinder of zinc *z*, thoroughly amalgamated, and completely surrounding the positive electrode, but prevented from touching it by means of the coarse canvas swathing *w*: the elements are contained in the ebonite receptacle *e*, *e*: the head of the rod *c* is run with lead, to which a terminal binding screw is fixed: this lead head and its junction with the graphite are coated with a mixture of equal parts of china clay and pitch, to prevent the deposition of moisture there: the electrolyte is a saturated solution of sal-ammoniac, the level of the liquid being 1½ inches below the top of the ebonite box.

At Fig. 2 is an illustration of the *rectangular* type, showing the internal arrangements of the cell. The positive electrode consists of a fluted carbon (graphite) plate *c*, on each side of which are placed three flat agglomerate blocks *b*, *b*, (equal parts of binoxide of manganese and graphite): these flat blocks press against the carbon plate *c* only at its extremities, thus permitting of the free circulation of the acid between them and the dissipation of the evolved gas: india-rubber bands, *T*, hold these blocks in their place against the central plate *c*, and at the same time maintains the positive electrode central, and prevents contact between it and the negative element: the bottom of the positive electrode rests in a wooden shoe having perforated sides, and lined with flannel, which serves to keep the two electrodes apart: the perforations permit of the free circulation through the flannel which acts as a screen: the negative electrode is a V-shaped amalgamated zinc plate *z*: the electrolyte is a saturated solution of sal-ammoniac: the elements are contained in a rectangular ebonite box *e*. In all other particulars the two types are identical.

The E. M. F. in each case is 2 volts, and the internal resistance 0·15 ohm to 0·2 ohm.

For the purposes of submarine mine firing 10 of these cells are connected up in series in a strong teak box, as shown at Fig. 3: ten such boxes (100 cells) constituting a firing battery.

Boats' Firing Batteries.—For experimental work with submarine mines fired from a boat, or for the firing of the spar torpedo a form of battery is required which shall not be affected by the motion of the boat in rough water.

A three-cell bichromate acid cell constructed by Ruhmkorff was tried by General Abbot for this work, and afforded very satisfactory results.

This battery consists of a closed ebonite subdivided case 9″ × 5″ × 2″ which may be carried hanging round the neck: the positive electrodes are square rods of carbon 0·4″ × 0·4″ × 3″: the negative electrodes are small cylinders of zinc surrounding the carbon rods: these six electrodes are attached to the ebonite cover, each pair entering its respective division in the ebonite case: the electrolyte (bichromate of potash) is contained in a receptacle in the bottom of the box.

To fire a fuze connected up to the two terminals on the top of the box, it is only necessary to invert the box, and thus cause the electrolyte to flow into the three compartments containing the carbon, and zinc elements. A firing key may be interposed in the circuit: to

PL. XIX

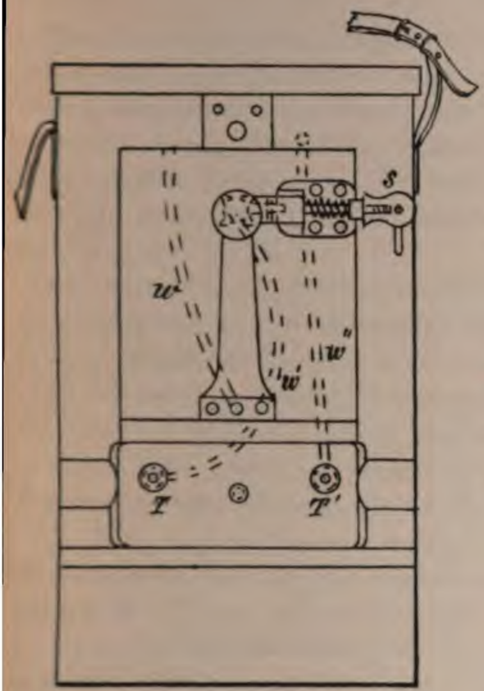


Fig. 1

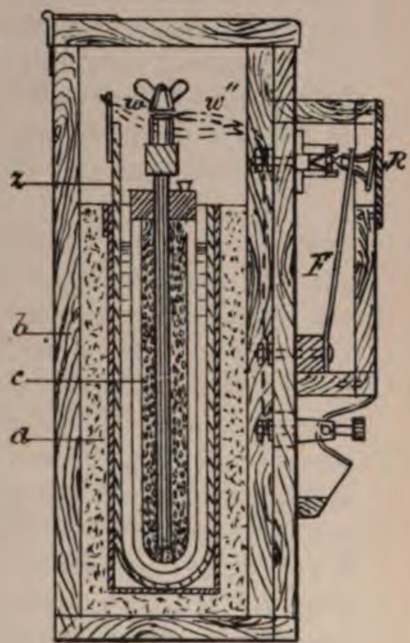


Fig. 2

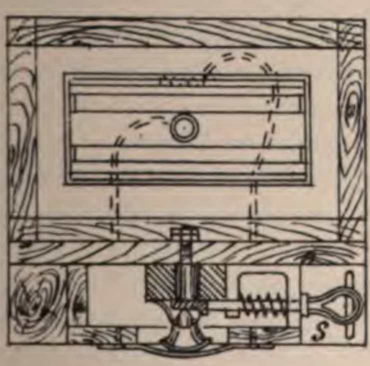


Fig. 3

fire it would only be necessary to invert the box and *then* press the firing key.

This is a very neat and compact form of boat firing battery, and to clean it, and renew the fluid it is only necessary to remove the lid.

This battery will fire a fuze through some 4 ohms resistance.

English Service Boat Firing Battery.—The form of battery used in the English naval service for firing spar torpedoes is shown in Pl. XIX. where Fig. 1 is an elevation: Fig. 2 a section: and Fig. 3 a plan.

This battery consists of one small Leclanché cell, similar in form and construction to the rectangular cell described above, with the addition of sawdust packing *a* for the purpose of preventing the spilling of the electrolyte which is kept 3 inches below the top of the box. *c* is the positive (carbon) electrode: *z* is the negative (zinc) electrode: *b* the wooden box containing the cell: *F* is the firing key: *T*, *T′* the fuze wire terminals: *w* the wire connecting the zinc element to the firing key: *w′* the wire connecting the firing key contact to the terminal *T*: *w″* the wire connecting the carbon element to the terminal *T′*: *R* is an india-rubber cover: on pressing down the key *F* the circuit between the battery and the fuze is completed. A safety arrangement *S* is provided to prevent premature explosion: this consists of a metal pin having an ebonite end inserted between the two contacts of the firing key, and provided with a strong spring: to fire the fuze this pin must be drawn and *held* back.

This battery is provided with a strap to enable it to be slung over the shoulder of the operator.

Firing Battery for Self-acting Mines.—In electrical self-acting mines a firing battery contained in the mine is required which shall only be rendered active by the act of the hostile vessel coming into contact with the mine. This may be secured by holding the electrolyte in a glass tube in direct communication with the electrodes of the battery, and the former arranged so as to be broken by the blow of the colliding vessel, as shown in Pl. III.

General Abbot proposes to use the following method, by which the necessity of a glass tube, and of arranging a means outside the mine for the breaking of the same, is obviated.

The electrodes of this battery are platinum foil and zinc each $1\frac{1}{4}'' \times \frac{1}{2}''$: four sets of these plates are arranged in a circular ebonite box, separated by vulcanite rubber diaphragms: the electrolyte (bichromate of potash) is contained in a reservoir in the bottom of the box, and in communication with the elements through a central hole. The connections are made as shown in the diagram in Pl. XX., Fig. 2, where *f* is the fuze.

The difficulty experienced in devising such a battery was due to the fact that the blow of the vessel striking the mine may take effect in *any* horizontal direction.

Experiment with this type of battery proved that with two, three, or four of the cells filled with the electrolyte, the fuze would be fired with 1·6 ohms, 1·1 ohms, and 1·0 ohm resistance respectively in the circuit.

A battery arranged upon these principles is now in use for the American system of self-acting electrical mines, which will fire the mine fuze through 2 ohms resistance in the circuit besides that of the battery itself.

Secondary Firing Batteries.—For the firing of submarine mines, the secondary battery is most admirably adapted, due to its high E. M. F., low internal resistance, and its constancy where only a small current is required; it possesses however the disadvantages of requiring to be recharged from time to time, either by another secondary battery brought to the mine station for this purpose, or by a primary battery, or lastly by means of a dynamo worked by either steam, gas, compressed air, or water power.

There is also a possibility of burning up the instruments in the circuit in the event of a short circuit occurring, owing to the extremely low internal resistance of this form of battery, but this cause of danger would be more likely to take place with the secondary cell used for the signal battery.

In Pl. XX., at Fig. 3, is shown an illustration of an E. P. S. new type S plate cell, as designed and constructed by the Electrical Power Storage Co.

This cell has an E. M. F. of 2 volts, an internal resistance of 0·02 ohm, and a capacity of 180 ampere-hours.

Signal and Testing Batteries.—*Signal* batteries are required to send a current through the mine circuit, in which is included the circuit closer in the mine, and the signalling and testing instruments on shore in the mine station: this current must be too feeble to fire the mine fuze, and yet powerful enough to work electro-magnets, by which means a signal is recorded, in the station instrument: this circuit may be closed and of low resistance, when the battery must be capable of supplying a constant current, or, as is more generally the case, it is only required to work on an open circuit, when the condition of constant current supply is not essential.

Testing batteries are required for two purposes, viz., for testing through the mine circuits with the mines actually laid down in position to enable the electrical condition of the system to be manifested at any moment: and for the measurement of electro-motive force and resistance, in connection with the firing batteries, cables, fuzes, &c.

The Sulphate of Copper, Two-fluid, Cell.—This cell, of which the original type was the Daniell, is one of the very best for supplying a constant and uniform current of moderate strength, and therefore is well adapted for signal and testing batteries on a closed circuit in connection with a system of submarine mines.

The ordinary form of Daniell cell is as follows:—

The positive electrode is a cylinder of copper open at both ends and perforated by holes, having an annular shelf on the upper part also perforated by holes: the negative electrode is a cylinder of zinc open at both ends, and is contained in a porous pot with its electrolyte (dilute sulphuric acid): the copper cylinder surrounds this porous pot, and the whole is placed in a glass jar with the electrolyte (saturated solution of sulphate of copper): to maintain the necessary saturation of this solution crystals of sulphate of copper are placed on the annular shelf before mentioned: a strip of copper connected to each of the electrodes serves to connect two or more such cells up in series or parallel. E.M.F. 1·079 volts.

The Watson Signal Battery.—The pattern of gravity (Daniell) cell which General Abbot considers as one of the best of its kind for use as a *signal* battery, in connection with submarine mines, is known as the "Watson" cell, and is formed as follows: the positive electrode zinc, annular and massive, is attached to the cover of the cell by metal rods: the negative electrode is an inverted lead funnel, the cylindrical part is 5 inches long and 2 inches in diameter, and the cone is 5½ inches in diameter at its base, and is pierced by several holes to admit of the free passage of the electrolyte (cupric sulphate):

the cylindrical part is protected by paint where it traverses the zinc solution: the elements are placed in a 6″ × 8″ glass jar covered by a porcelain disc: the cupric sulphate solution rests on the lower part of the jar, and the zinc solution on the top of the cupric sulphate, the two solutions not mixing by virtue of the difference of their specific gravities, provided the cell be protected against mechanical disturbance.

As a large deposit of copper forms on this lead cone, it is advisable to cut one side open to avoid any wedging in the jar.

E. M. F. 1·08 volts: internal resistance from 3 to 6 ohms.

General Abbott sums up the advantage of this type of gravity (Daniell) cell as follows: "no porous cell, no evaporation, negative plate of large surface extending entirely through the solution of cupric sulphate, facility of charging whenever desirable, a receptacle for the droppings from the zinc where they do not mingle with the crystals of the sulphate or cover the negative plate, and lastly, convenient binding posts on the cover."

Minotti Testing Cell.—The Minotti cell is a type of Daniell well adapted for the purposes of rough testing, as when placing mines in position, and such like operations.

In Pl. XX. at Fig. 4, a section of this cell is shown, and at Fig. 5 a plan of the top showing the 20-ohm galvanometer it is connected up with: the cell consists of a copper cup *c*, containing some crystals of cupric sulphate, and covered with a fearnought diaphragm, placed at the bottom of an ebonite cell *E*: over this diaphragm is placed some sawdust, and resting on the top of this is a disc of zinc *z*, on another piece of fearnought: the upper part of the zinc, and its connection with the insulated wire *w*, are carefully insulated.

E. M. F. 1·1 volts: internal resistance 6 to 7 ohms.

The connections are made as follows: one of the wires w^4 of the object to be tested is attached to the terminal *t*, in connection with the positive electrode *c* by the wire w': the other main wire w^3 is attached to the terminal t' of the galvanometer, Fig. 5: t'', the other terminal of the galvanometer, is connected by a short piece of wire w'' to the contact key *k*: the negative electrode *z* is connected to the other contact of the key *k* by the wire *w*: thus on pressing down the key *k*, the circuit through the object to be tested, the galvanometer, and the battery is completed. To steady the galvanometer

PL XX

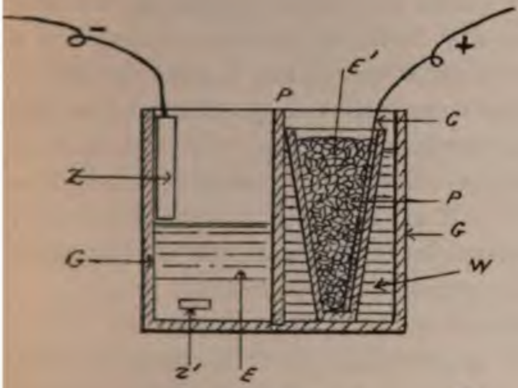


Fig. 1

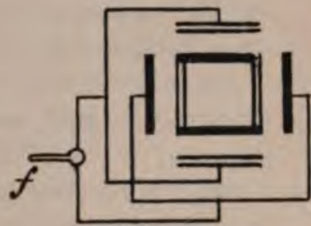


Fig. 2

Fig. 3

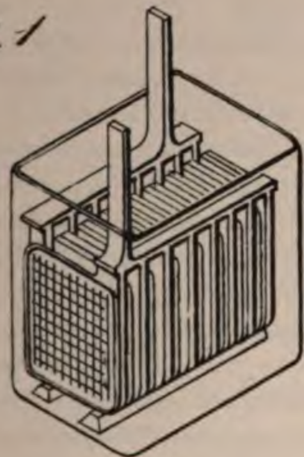


Fig. 4

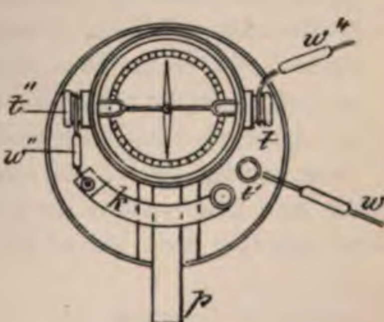


Fig. 5

needle, a bar magnet *p*, Fig. 5 is used. The whole of the apparatus is enclosed in a leathern case fitted with a cover and strap.

Leclanché Signal and Testing Cells.—For *signalling* purposes 20 Leclanché cells of the agglomerate type known as No. 3 is well adapted.

E. M. F. 1·55 volts, and internal resistance of each cell 0·8 ohm.

For the purposes of *testing* the agglomerate form of Leclanché cell generally used is known as the No. 769 type.

E. M. F. 1·55 volts, and internal resistance of each cell 2·0 ohms.

Standard Cells.—A specially devised cell is necessary in electrical testing as a measure of the voltaic standard of E. M. F., by which to compare the E. M. F. of the working cells, whether of the firing, signal, or testing batteries.

For this purpose either a form of the Daniell cell, or the Clark, or De La Rue element is commonly used.

In Pl. XX., at Fig. 1, a section of the Post Office Pattern Standard Daniell cell is shown, where *G* is a glass vessel divided into two compartments by the glass partition *P*: the negative element is formed of a zinc plate *z* pure, and well amalgamated, and hung so as to almost reach to its electrolyte (saturated solution of sulphate of zinc) *E*: the positive electrode is a copper strip *C*, which is placed in its electrolyte (sulphate of copper with crystals) *E′* contained in a porous pot: surrounding this porous pot is water *W*.

When required for testing purposes, the porous pot, with its contents is removed from the water (*W*) compartment and inserted into the electrolyte *E*. This cell gives an E. M. F. of 1·07 volts, and is very constant.

B. Measuring Instruments.

For actual work in a system of defence by submarine mines, only the very simplest forms of electrical measuring instruments would be required, such as the single, and three-coil detector galvonometer, for rough tests as to the efficiency of joints, &c., for conductivity, and as to the state of the mine circuit generally: an astatic galvanometer, Wheatstone bridge, and thermo-galvanometer, together with a commutator, and firing keys in connection with the test table and shore instrument situated in the mine stations, for each set of mines.

In the mine depôt it will be necessary, however, to provide electrical instruments for the purposes of elaborate tests in connection with the cables, circuit closers with their delicate relays, fuzes, batteries, &c., during and after construction, and in the proving of the efficiency of the electrical gear obtained from private manufactories.

It would of course be impossible to enumerate and describe all the electrical instruments which it might be considered necessary to provide by those in charge of the different torpedo depôts for these purposes, and therefore only a brief description of those instruments absolutely required with a system of defence by submarine mines will be given here, as enumerated in the following list:—

1. Siemens Universal Galvanometer.
2. Three-coil Galvanometer.
3. Detector Galvanometer.
4. Thermo-Galvanometer.
5. Direct reading Voltmeter.
6. Direct reading Ammeter.
7. Steel-yard Ammeter.
8. Low constant Voltmeter.
9. Commutator.
10. Firing Keys.
11. Shunt.
12. Rheostat.
13. Resistance Box.
14. Wheatstone Bridge.
15. Telegraph Instruments.

Siemens Universal Galvanometer.—A complete description of this very useful galvanometer with diagrams for the various tests will be found in the previous edition of this work, and as this information also accompanies each instrument supplied by Messrs. Siemens Brothers, it will be unnecessary to repeat it here.

The Siemens Universal Galvanometer is an instrument combining in itself all the arrangements necessary for the following operations:—

1. For measuring electrical resistances.
2. For comparing electromotive forces.
3. For measuring the intensity of a current.

PL. XXI

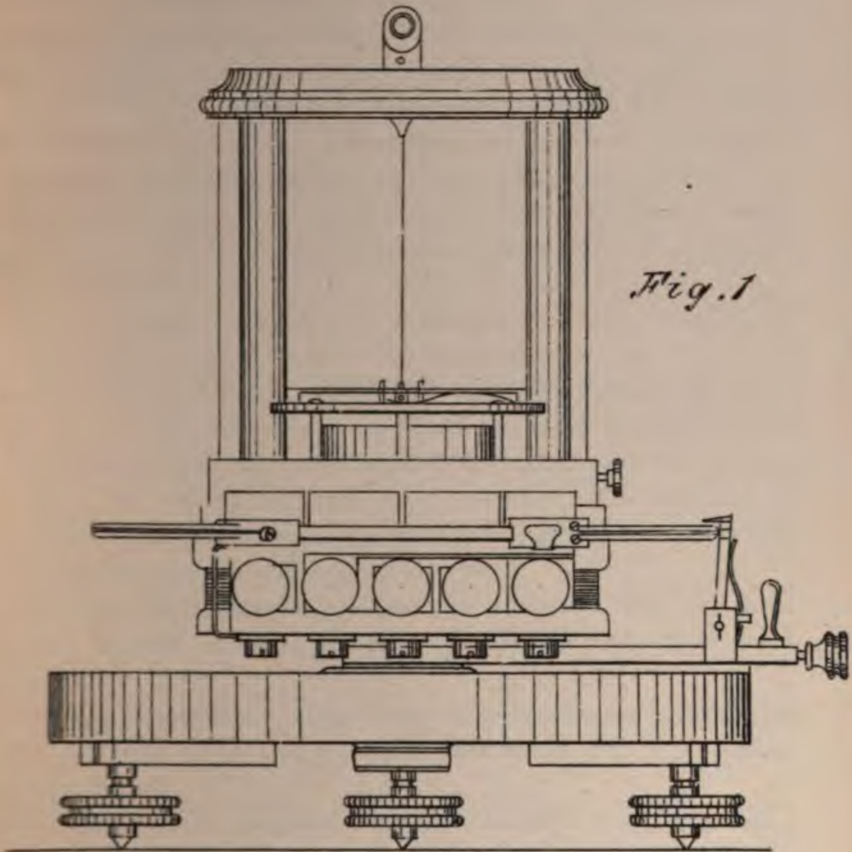


Fig. 1

Fig. 2

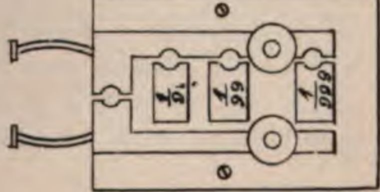


Fig. 3

The instrument which is shown in Pl. XXI. consists of a sensitive galvanometer which can be turned in a horizontal plane, combined with a resistance bridge (the wire of which bridge instead of being straight is stretched round part of a circle). The galvanometer has an astatic needle, suspended by a cocoon fibre, and a flat bobbing frame wound with fine wire. The needle swings above a cardboard dial divided in degrees; as however, when using the instrument the deflection of the needle is never read off, but the needle instead always brought to zero, two ivory limiting pins are placed at about 20 degrees on each side of zero.

The galvanometer is fixed on a graduated slate disc, round which the platinum wire is stretched. Underneath the slate disc three resistance coils of the value of 10, 100, and 1000 Siemens units are wound on a hollow wooden block, which protrudes at one side, and the projection carries the terminals for the reception of the leading wires from the battery and unknown resistance. The adoption of three different resistance coils enables the measuring of large as well as small resistances with sufficient accuracy.

The whole instrument is mounted on a wooden disc, which is supported by three levelling screws, so that it may be turned round its axle.

Three-coil Galvanometer.—The three-coil galvanometer is illustrated in Pl. XXII. where Fig. 1 is a general sketch, and Fig. 2 a diagram of the connections.

It consists of a magnetic needle (usually hung vertically) pivoted in the centre of three coils of insulated wire *c*, *c'*, of 2, 10, and 1000 ohms resistance respectively, and having an index needle attached to move with it: the index needle moves over a dial, Fig. 1, marked in degrees from zero to 90° each way: one wire of each of the coils is connected to a brass plate *b*, *b'*, *b''*, respectively marked with the amount of the resistance of its respective coil: the other end of the coils is connected to one pole of the battery it is connected up with: the other pole of which is connected to the terminal *t*: *a* is a strip of brass separated from the brass pieces *b*, *b'*, *b''* by spaces which can be bridged over by a plug, and having the terminal *t'*: by means of the plug either the 2, 10, or 1000 ohms resistance can be put into the circuit.

Detector Galvanometer.—The detector galvanometer is similar in all respects to the three-coil galvanometer previously described, with the exception that there is only *one* (high) resistance coil.

Thermo-Galvanometer.—A thermo-galvanometer is an instrument used to ascertain the power of a firing battery to fuze the iridio-platinum wire bridge of the mine fuzes.

The form of thermo-galvanometer adapted for submarine mine work is as follows: two ebonite studs fitted with brass connecting screws are fixed to the lid of a box containing certain resistance coils and connected up in circuit with them: these ebonite studs are placed about 0·3 inch apart, between which a piece of wire to be tested is stretched.

Another form of thermo-galvanometer, which is very portable and compact, is shown in section, in Pl. XXII. at Fig. 5. It consists of a wooden box *a*, with an ebonite cover *e*, containing a resistance coil *r*: *b*, *b′*, two standards between which is fixed the card containing a number of lengths of the iridio-platinum wire to be tested: *F* is a firing key in connection with the terminal *t*, which terminal is connected with one end of the resistance coil wire: the other end of this coil wire is attached to the terminal *t′*, which terminal is carried to one of the standards *b′*: two other terminals, *t″* and *t‴*, are provided, *t″* being connected to the firing key contact *f*, and *t‴* to the standard *b*: the two terminals *t*, *t′* are provided for the purpose of being able to cut out the resistance coil *r* when required, which is effected by short circuiting by means of a piece of thick wire joined across these terminals.

Direct reading Voltmeter and Ammeter.—These instruments enable the E. M. F. and current to be read off direct in volts and ampères.

Messrs. Siemens Bros. have designed two such instruments, which have no permanent magnets in their construction, never require to be recalibrated, and may be left constantly on the circuit.

The ammeter is constructed on the following principle: a soft iron core, mounted on pivots, and provided with two arm projecting pole pieces, is surrounded by a coil of wire, the straight ends of which pass over these projections: a current passing through the coil magnetises the core, and the arm projecting pole pieces are acted on by the current passing through the straight conductors at the coil ends, and the deflection thus caused is balanced by the usual torsion spring.

The voltmeter is made on the same principle, two separate fine

PL. XXII

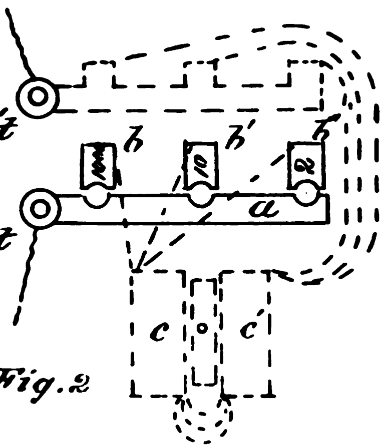


Fig. 2

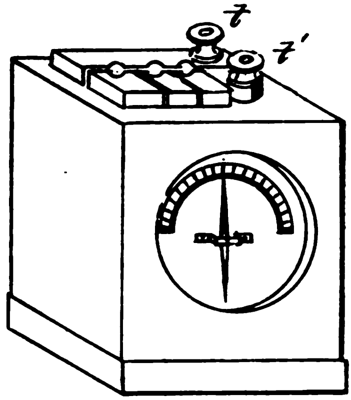


Fig. 1

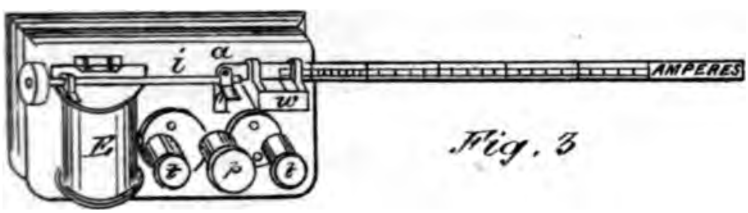


Fig. 3

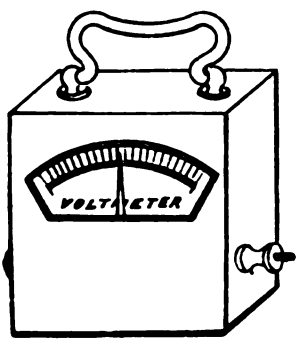


Fig. 4

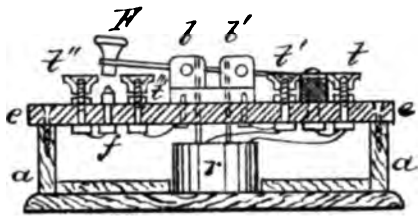


Fig. 5

wire coils being used, one to magnetise the core, and one, placed parallel to the arm projections, to give the necessary deflecting force.

This principle enables these instruments to be made to give direct readings.

The Steel-yard Ammeter.—The steel-yard Ammeter shown in elevation in Pl. XXII. at Fig. 3 is constructed by the Electrical Power Storage Co. (Drake and Gorham's patent), and has been designed with a view to obtaining a simple and mechanical arrangement which can with safety be placed in unskilled hands. As no permanent magnets are employed, the instrument will remain correct for any length of time, and owing to the length of the scale the readings can be accurately taken.

The ammeters, which are direct reading, are made to read up to 1½, 20, 40, 60, 80, 100, 120, and 250 ampères.

This ammeter consists of a solenoid E: a soft iron rod i pivoted at a, and joined to a German silver yard on which the scale is marked: movable sliding weight w: two terminals t, t, the circuit between which is made or broken by the plug p: a compass is also provided for showing direction of current.

When no current is passing and the weight w is placed at zero, the yard is perfectly balanced: as soon as the circuit is closed the solenoid sucks down the soft iron rod, and by sliding the weight w along the scale to the point at which it overcomes the pull of the solenoid, the precise current sent through the solenoid coil is then measured by the reading on the scale at that point.

Low Constant Voltmeter.—This instrument, constructed by the E. P. S. Co., is a very useful one for the purposes of testing the E. M. F. of each cell of a battery. It is shown in elevation in Pl. XXII. at Fig. 4.

It measures electromotive forces between 0 and 2·5 volts with great accuracy, and at the same time indicates the direction of the current.

The internal construction of this instrument is somewhat similar to other deflecting voltmeters, and consists of a soft iron needle pivoted between the poles of a magnet: the effect of closing the circuit being the repulsion of the needle from its normal position either to the right or to the left, according to the direction of the current.

Very little fear need be entertained of alteration through the use of permanent magnetic pole pieces, probably not more than 0·4 volt per annum, and this change is not important, as the object of the test made with this instrument is to ascertain the comparative power of each cell rather than the precise E. M. F.

Commutator.—A commutator is a key instrument by which the direction of currents may be changed at will, or by which a varying number of cells may be switched into a circuit.

In Pl. XXIII. at Fig. 5 a diagram of the connections of such an instrument is shown. *k*, *k'* are two keys connected respectively to the line at *L* and to the earth at *E* of the circuit through which the currents are to be sent: in their normal position they press against the bar *a*, to which the wire *w* from the positive electrode of the battery is connected: *b* is another bar placed below the keys, to which the wire *w'* of the negative electrode is connected. If the key *k* be pressed down in contact with the bar *b*, a negative current from the battery flows into the line: if the key *k'* be similarly pressed down a positive current flows into the line.

Firing Key.—This instrument is intended for the making and breaking of the firing circuit, and is constructed on the same principle as all others intended for a similar purpose, with the addition of a safety locking arrangement by which to prevent the premature making of the circuit.

One form of a firing key is shown in Pl. XXIII., where Fig. 1 is a vertical section. It consists of a wooden box *A*, weighted with lead at the bottom, to steady the key when in use on a table, &c.: *e* is a piece of ebonite in which is fixed the terminals *t'*, the pivot *p* of the firing key *f*, and the firing key contact piece *c*, which are thus insulated one from another: the terminal *t* is connected to the contact piece *c*, and the terminal *t'* to the firing key pivot; thus the circuit between the fuze and the battery (the other terminal of the fuze and battery being to earth) is completed when the key *f* is pressed down in contact with *c*: the spring *d* keeps the key off the contact piece *c*: *s* is the safety or half-cock arrangement, which when in position prevents the firing key from being pressed down.

For the purpose of firing a number of mines by the "observation" or "at will" method, a number of these keys may be arranged on one stand, when they form a series of firing keys.

A Shunt.—A shunt is a resistance coil, or coil of fine wire used to divert some definite portion of the current, taking it past the galvanometer instead of through its coils: thus the sensibility of a galvanometer may be varied to any extent.

In Pl. XXIII. at Fig. 3 is shown the arrangement of a shunt with a galvanometer: g is the galvanometer coils: s the shunt coil: w, w the wires of the circuit to be tested. Then suppose the shunt to be $\frac{1}{9}$th the resistance of the galvanometer, 9 parts of the current will pass through the shunt s, and 1 part through the galvanometer: therefore only $\frac{1}{10}$th of the deflection is shown on the galvanometer of what would have been shown had no shunt been used (supposing a mirror galvanometer to have been used).

Galvanometers are now usually provided with shunts equal to $\frac{1}{9}$th, $\frac{1}{99}$th, and $\frac{1}{999}$th of the galvanometer resistance; by these the sensibility of the instrument is increased a thousand-fold.

With a constant current, and an instrument whose deflections are proportional to the currents, and where d, d' are respectively the deflections without and with the shunt, the following formula is generally practicable:

$$d : d' :: g + s : s.$$

The resistance of the shunt will in all cases diminish the resistance of the circuit, so that unless the resistance of the galvanometer forms no sensible part of the whole resistance the *deflections* will not be altered in the above proportion. In this case, suppose R to be the resistance of the circuit, except the galvanometer; then $R + g$ will be the whole resistance when no shunt is used, and $R + \frac{g\,s}{g + s}$ when the shunt is used. Compounding this ratio with the former one, then

$$d : d' :: R\,(g + s) + g\,s : (R + g)\,s$$

for the deflections due to a constant E. M. F. with and without the shunt.*

A Rheostat.—A rheostat is an instrument used for the comparison of resistances, and is often employed in connection with the thermo-galvanometer.

Wheatstone's rheostat is shown in elevation in Pl. XXIII. at Fig. 4. It consists of two cylinders A and B, one of brass and the other of non-conducting material, and so arranged that a copper wire

* Jenkins' 'Electricity and Magnetism.'

can be wound off the one cylinder on to the other by turning the handle *C*. The surface of the insulated cylinder *B* has a screw thread-cut in it for its whole length, in which the turns of the copper wire may lie, so that its successive convolutions are well insulated from each other. Two binding screws, *t*, *t'*, connected with the ends of the copper wire are provided, to which the circuit wires are attached. A scale is provided, by means of which the number of convolutions on *B* can be read off; and parts of a revolution are indicated on a circle at one end. The handle *C* can be shifted from one cylinder to the other.

Supposing the rheostat introduced into a circuit, and the whole of the copper wire wrapped on the metal cylinder *A*, then, on account of the large section of this metal cylinder, its resistance may be entirely neglected, but for every convolution of the wire on the non-conducting cylinder *B*, a specific resistance is introduced into the circuit. The amount of resistance can thus be varied as gradually as desired by winding on and off the cylinder *B*.

Resistance Box.—The general arrangement of a resistance box is shown in the diagram, Pl. XXIII., Fig. 2.

Between two terminal binding screws *t* and *t'* secured on a vulcanite slab are fixed a series of brass junction pieces, *a*, *b*, *c*, *d*, *e*; each of these is connected by a resistance coil to its neighbour, as shown at 1, 2, 3, and 4. A number of brass conical plugs with insulating handles of vulcanite are provided, which can be inserted between any two successive junction pieces, as between *a* and *b*, or *b* and *c*.

With all the plugs inserted, the electrical current will flow direct from *t* to *t'*, the large metallic junction pieces directly connected by the plugs would offer no sensible resistance; but if all the plugs were removed, then the current would flow through each of the coils 1, 2, 3, and 4, and the resistance in the circuit would be the sum of the resistances of those four coils. With the plugs arranged as in the figure, the current would flow through coil 4 only, and the resistance in the circuit would be equal to the resistance of that coil.

Wheatstone's Balance.—The electrical conductivity of a body is determined by ascertaining the ratio between the resistance of a certain length of the conductor in question, having a given section, to that of a known length of a known section of some substance taken as a standard.

PL. XXIII

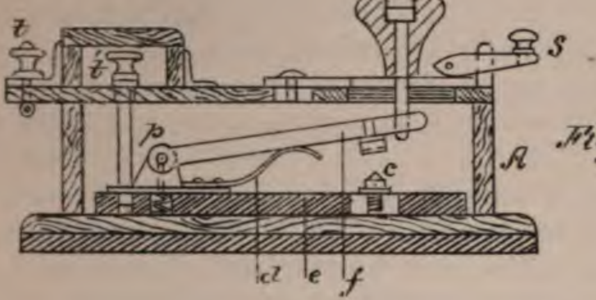


Fig. 1

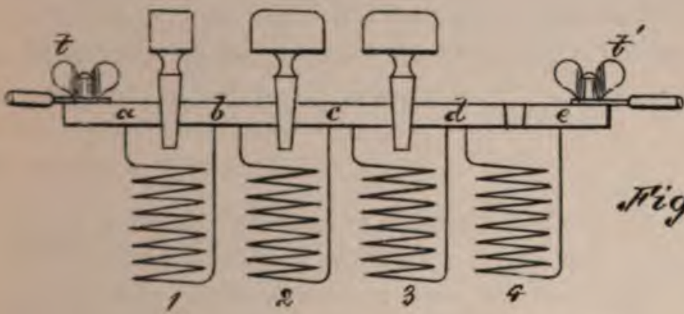


Fig. 2

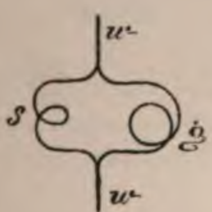


Fig. 3

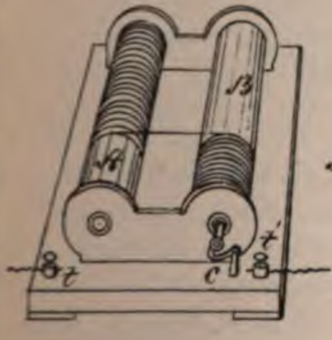


Fig. 4

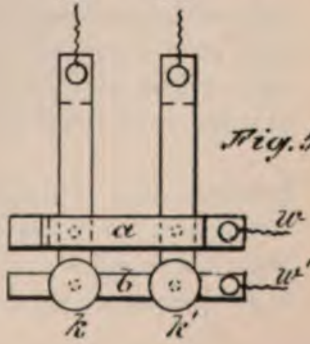


Fig. 5

For this purpose Wheatstone's bridge in connection with a box of resistance coils is the most convenient method.

In Pl. XXIV. at Fig. 2 is shown Wheatstone's balance (Post-office pattern), and at Fig. 1 the apparatus is reduced into the form of a parallelogram, which is the usual diagram of Wheatstone's bridge. The theory of the bridge is as follows:

Four conductors, *A B*, *B C*, *A D*, and *D C* are joined at *A* and *C* to the poles of a battery *H*; the resistance between *A* and *B* is r; that between *A* and *D* is R; that between *D* and *C* is R^1; and that between *B* and *C* is x, the unknown resistance to be measured. A convenient constant ration is chosen for R, and r, such as equality 1 to 10, 1 to 100, or 1 to 1000; and then R^1 is adjusted until no current flows through the galvanometer *G*; when this is the case we have $R : r = R_1 : x$, or $x = \frac{r}{R} R_1$; so that if $r = \frac{R}{100}$, x will be equal to $\frac{R_1}{100}$.

Two keys *a* and *b* are inserted; the current is wholly cut off the four conductors until contact is made at *a*; and then after the currents in the four conductors have come to their permanent condition, contact is made at *b* to test whether any current flows through the galvanometer. The three resistances R, R^1 and r and the resistance of the galvanometer should be small if x is small, and great if x is great.

The conductors *A B* and *A D* of the bridge are each formed of three resistance coils having a resistance of 10, 100, and 1000 ohms respectively, inserted between the terminals *B* and *D* of the balance, Fig. 2.

The conductor *D' C* is formed of a set of resistance coils from 1 up to 4000 ohms, amounting altogether to 11,110 ohms, inserted between the terminals D^1 and *C* of the balance; in the balance, a brass plug being inserted between the terminals *D* and *D'*, they may be considered as one terminal *D*. The wire x to be tested is connected to the terminals *B* and *C* of the balance.

Measurement of Resistances.—When a resistance is to be measured that is within the range of the coils in R^1, R and r are made equal. The needle of the galvanometer will move in a different direction, either to the right or to the left, according as the resistance in R_1 is greater or less than the line wire x. The needle remains at zero only when the resistance in R_1 is equal to that in x. For $r : R :: R^1 : x$.

When the resistance of x is greater than that of R^1, as in an insulation test, the resistance in r is made *less* than in R, in order that r and R may have such a proportion one to the other as will enable the coils in R, to balance a resistance in x, greater than their own, that is to say, greater than 11,100 ohms; thus $r : R :: R^1 : x$, or suppose 10 (r) : 1000 (R) :: 10,000 (R_1) : x, then the resistance in the line under test would be 1,000,000 ohms.

When the resistance to be tested is less than that of the least coil in R^1 (1 ohm), then r is made greater than R. Thus in this case $r : R :: R^1 : x$, might be arranged as 100 : 10 : : 2 : x, giving the resistance of the circuit under test as 0·2 ohm.

In all cases the battery key a should first be depressed, then the galvanometer key b, making very short contacts with the latter (just sufficient to show the direction of the deflections of the needle) until the resistance R^1 is nearly adjusted, otherwise considerable time will be lost in making a series of tests, owing to the swing given to the needle. When once the resistance in R^1 is adjusted and a balance obtained, it should be ascertained whether the needle will remain steady when contact is made and broken.

Telegraph Instruments.—Telegraph communication is very necessary either between submarine mine stations, or between boats employed in laying out mines and the station connected with them, or again, between a ship and its guard boats.

For permanent work the Morse recording telegraph instrument is usually employed.

For boat work the Morse sounder instrument is generally adopted.

One core of the seven-cored multiple cable is often utilized for telegraph purposes.

Both of these instruments more particularly belong to telegraph work, and are besides too well known to need description here.

PL. XXIV

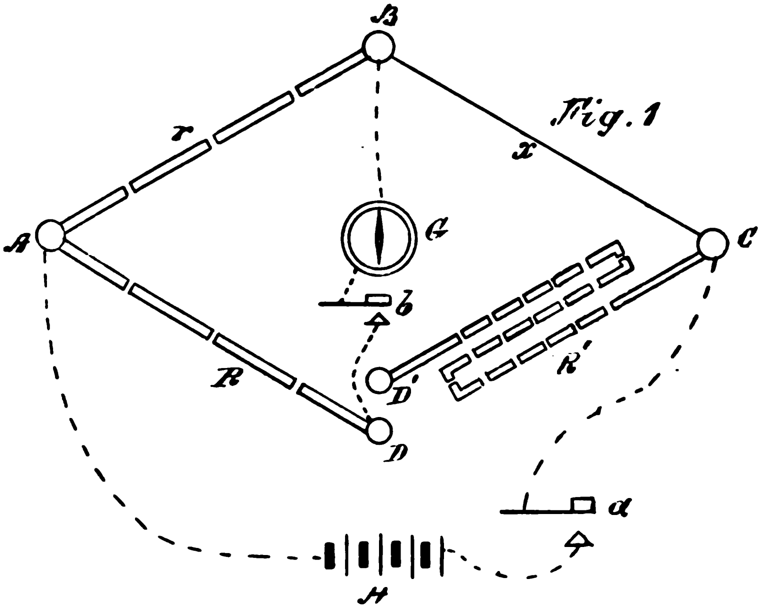
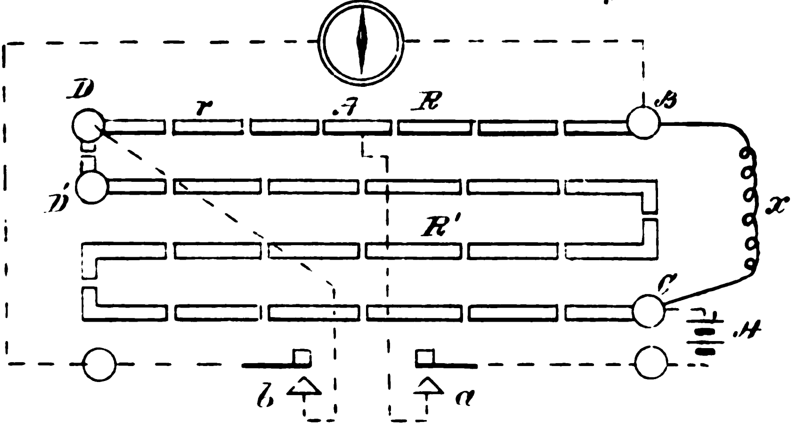


Fig. 1

Fig. 2



CHAPTER V.

DIRECTIVE APPARATUS.

DIRECTIVE instruments are necessary adjuncts of a system of controlled submarine mines for providing the operator in the mine station with the means whereby to control the firing of the mines, and also by which the fact of a particular electro-contact mine having been struck by a passing vessel is indicated to him by the ringing of a bell in the station: further, such are required for the purpose of observing the exact moment of a ship, attempting to cross a mine field, being directly over any particular mine, in observation firing, so that the mine may be exploded "automatically" or "at will," or left unexploded as circumstances demand.

In fact all the various operations of a system of controlled mines are directed by these instruments, which include the following:—

1. The Service Shutter Apparatus.
2. The McEvoy Shutter Apparatus.
3. Intersectional Arc (observation) Instruments.
4. The Siemens' Distance Measurer.

The Service Shutter Apparatus.—The shutter apparatus is an electrical instrument arranged to automatically switch the firing battery into the circuit of a mine at the instant of that particular one being struck by an enemy's vessel, and at the same time to indicate this fact, and the number of the mine by the dropping of a "shutter" on to a bell; each mine is provided with its own shutter apparatus, the shutter of each being marked with the number of the mine it is in circuit with.

The firing battery may, however, be "cut out" of the mine circuit, in which case on a vessel striking any particular mine this would merely cause its shutter to drop and ring its bell, but the mine would not be exploded, and the operator could then either fire it by inserting a plug, or permit the vessel to pass unharmed over the mine.

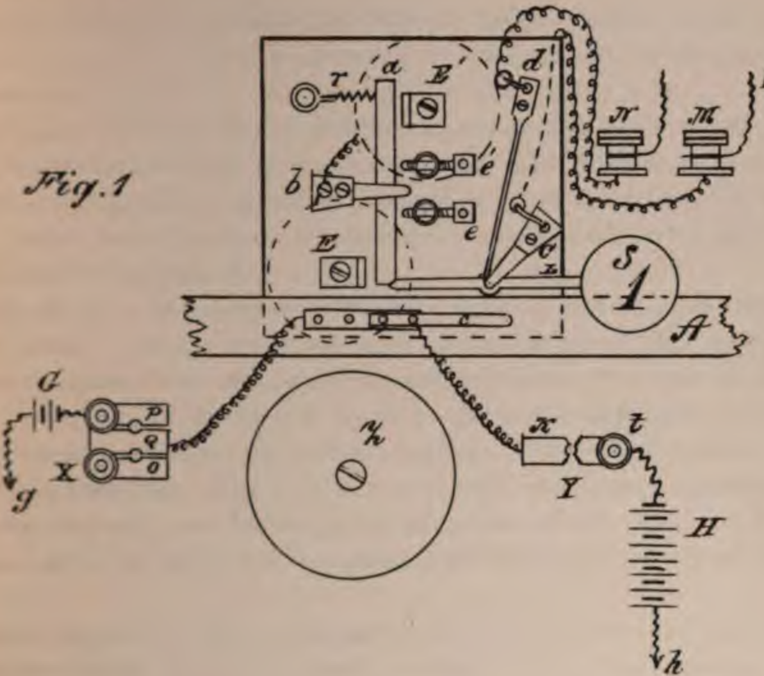
The shutter apparatus can also be used with the intersectional arc instruments in connection with observation firing, when the latter performs the function of the ship striking a mine by putting the signal battery to earth, thus causing the shutter of that mine to drop, and exploding it if the firing battery be in circuit.

The shutter apparatus about to be described is the one constructed by Messrs. Siemens Brothers, but it is in principle identical with the form of shutter apparatus usually employed in connection with a system of controlled submarine mines, and differs only in a few details of construction from the English service instrument.

At Pl. XXV., Fig. 1, is shown a diagram of a single shutter apparatus, where *A* is a piece of ebonite to which all the working parts are attached: *E*, E^1, are two electro-magnets, whose coils are connected up in series; *a* is the armature revolving round a pivot at *b*; *r* is a spiral spring of just sufficient strength to hold the armature off the poles of the electro-magnets until the current from the signal battery (passing through its coils) is powerful enough to cause the armature to be pulled over; *e*, e^1 are two adjustable stops; *S* is the shutter; *L* the shutter lever pivoted at the point of the connecting piece *C*; *d* is a connecting metal strip terminating in a platinum point, and so arranged with the lever *L*, that it is only in contact therewith when the shutter is in the horizontal position, as shown in the diagram; *c* is a double contact spring between which the lever *L* falls when the shutter drops; *N* and *M* are two main terminals attached on the top of the instrument, the former in connection with the strip *D*, and the latter with the connecting piece *C*; the *N* terminal is used for connecting up the telescopic arc, and to the *M* terminal the mine cable is attached; the number on the shutter indicates that this instrument is in circuit with No. 1 mine; *G* is the signalling battery, one pole of which is put to earth at *g*, and the other is connected to the brass plate *P* of the com-

PL. XXV

Fig. 1



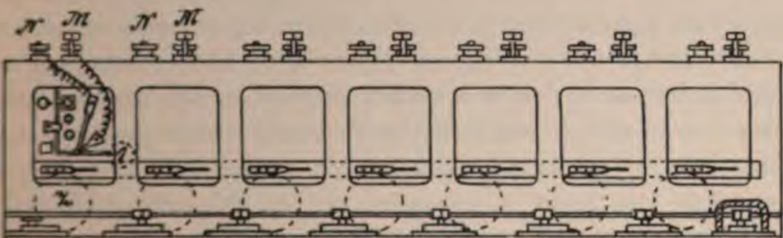


Fig. 2

Fig. 3

mutator X; H is the firing battery, one pole of which is put to earth at h, and the other is connected to the terminal t of the plug connecting piece Y.

The connections of this instrument are as follows: one end of the electro-magnet coil is connected to the middle piece Q of the commutator X; the other end of this coil is attached to the strip d; the double contact spring c is connected to the second part k of the plug connecting piece Y.

As shown in the diagram, both the signalling and firing batteries are cut out of circuit, but on inserting a brass plug between P and Q, a current passes from the signalling battery through the coils of the electro-magnets to the strip d, by it to the connecting piece C, and from these it branches off to the terminals N and M respectively; then supposing the mine only in circuit with this shutter apparatus, the current will pass by the cable R to the circuit closer in the mine and so to earth, thus completing the circuit of the signalling battery.

By reason of a high resistance in the circuit closer, the current from the battery G is not powerful enough to cause the armature of the electro-magnets E, E^1 to be attracted against the spring S; but on the mine being struck by a passing vessel, this high resistance is short circuited by the action of the circuit closer, and then the current from the battery G becomes strong enough to cause the armature a to be attracted, and so releases the lever L of the shutter S, which lever in falling breaks contact between it and the strip, and opens the circuit of the battery G, and then continuing its fall makes contact with the double contact piece c, while the shutter S strikes its bell Z: if a plug has been previously inserted between the contact pieces t and k of Y, the firing battery current is then automatically switched into the mine circuit through the contacts, and the mine is exploded: should this plug, however, not have been inserted, the mine would remain unexploded, and merely the fact of this mine having been struck be recorded: the operator at the mine station where the shutter apparatus is placed may then fire the mine if he so desire, by merely inserting the plug between T and K. If the mine is not exploded on its shutter falling, it is only necessary to replace its shutter in the horizontal position to render it ready for use again: if, however, the mine is exploded, the shutter is left down, and the plugs between the contact pieces *P* and *Q*, *t* and *k*, removed.

The manipulation of this shutter apparatus in combination with the telescopic arc for observation firing is explained at page 112. At Pl. XXV., Figs. 2 and 3, is shown a front view and plan of a box of seven of these shutter instruments: the brass contact pieces *P* are joined together, and the double contact pieces *c* as well: a box with lock and key is fitted over the firing plug contact *Y*, for safety purposes, as when this box is closed the plug cannot be inserted.

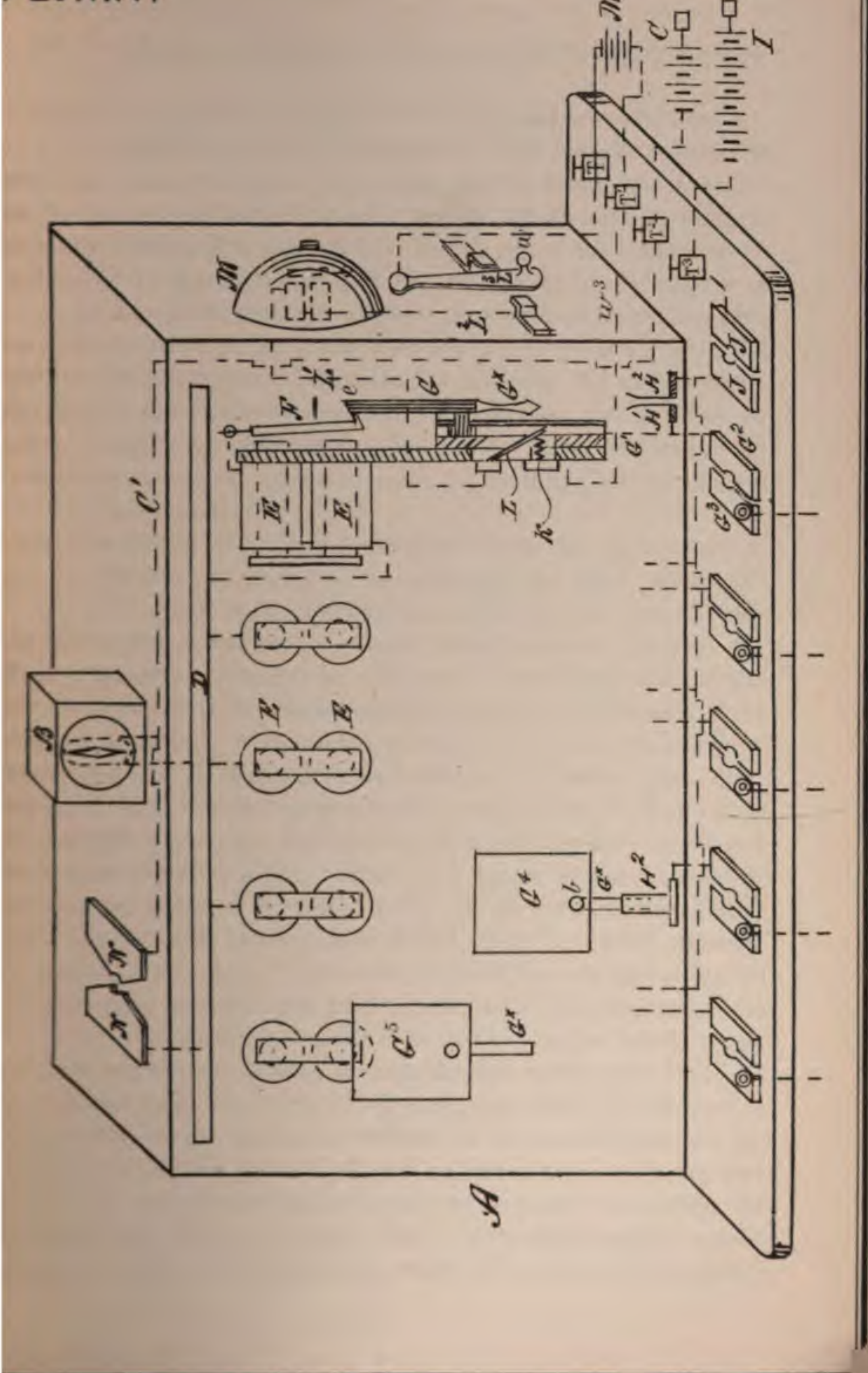
The McEvoy Shutter Apparatus.—The McEvoy shutter apparatus differs from the service instrument previously described, in that only *one* electric bell is provided, which serves for all the mines, and which continues to sound until stopped; in the arrangement of the shutter and the various circuits; also in the use of a galvanometer which may be put in or out of circuit at will.

In Pl. XXVI. is shown a front elevation of this shutter apparatus, with a side view of one of the shutter electro-magnets, and all the circuits.

A is the box in which the whole of the apparatus is contained, provided with a hinged glass front: *B* is a galvanometer: *N*, *N* are the galvanometer switch plates: G^2, G^3, with a terminal on the latter, are the mine switch plates, one set being provided for each mine: *J*, *J* are the firing battery switch plates: *M* is an ordinary electric continuous ringing bell, provided with the key L^3. The shutter apparatus (one for each mine) consists of two electro-magnets *E*, *E*: an armature *F* provided with a catch: a shutter *G*, shown in elevation at G^5, provided with a knob *b*, and a metal arm G^x: a spring *L*, and a spiral *k*: lastly two spring metal blades H^1, H^2. The shutter is arranged to *drop* between vertical guides, so that the arm G^x passes into and makes contact between the blades H^1, H^2, as shown at G^4.

The arrangement of the shutter apparatus, which is the same for each mine, is as follows: the armature *F* of the electro-magnet *E*, and the head of the shutter *G*, are each provided with a catch as at *e*, by which means the shutter is held up, as at *G* and G^5, unless the armature *F* be attracted to the poles of electro-magnet *E* by an electric current passing round the coils of the magnet, or be pushed thereto by hand, when the shutter immediately drops down as shown

PL. XXVI



at G^4; it may then be replaced in the position G by lifting it up by the knob b.

The various circuits contained in this apparatus are as follows:—

1. The Bell Circuit.—M^1 is the battery which operates the electric bell M, one pole is connected to the terminal T in electrical connection by the wire w with the bell key L^3: one of the wires L^2 of the bell magnet is connected to the left key contact piece: the other wire L^1 is attached to the spring L: and the other pole of the battery is connected to the terminal T^1, which is in electrical connection with the spiral k by the wire w^3: thus with the key L^3 pushed over to the left contact the bell will ring, when by dropping the shutter S the spring L is forced into contact with the spiral k: the bell can be stopped ringing by pushing the key to the right contact, or by breaking the contact between L and k, *i.e.* by lifting up the shutter into its normal position.

2. The Signal and Testing Circuits.—C is the signal battery, one pole of which is connected to earth, and the other pole to the terminal T^2, which is in electrical connection by the wire C^1 with one end of the galvanometer coil, and with the switch plate N; the other plate being attached to the bar D: the other end of the galvanometer coil is also connected to the bar: one end of each of the electro-magnet coils is connected to the bar D: the other end of the magnet coil is attached to its armature: the switch plate G^2 is connected to the shutter guides by the wire G^1: by plugging either of the switch plates, and leaving the other switch plates unplugged the current from the signal battery then passes by the terminal T^2 through the galvanometer coil to the rod D, through the shutter magnet coils E, E of the mine which is to be tested, through its cable to the fuze in the mine and by earth back to the battery C: the deflections shown on the galvanometer attest the efficiency of its circuit as to conductivity: each of the mines may be tested in this way: the current thus passing through the coils of the shutter magnet is not under these conditions strong enough to cause its armature to be attracted, so the shutter is retained in its normal position: by plugging the switch plate N, N, the galvanometer is cut out, and if then the mine under test be struck by a vessel, a resistance in the mine itself will by this cause be cut out, and the signal current will then become strong enough to cause the armature of the shutter

electro-magnet of this particular mine to be attracted to the poles of the magnet, releasing its shutter, which in dropping will cause the spring *L* to make contact with the spiral *k*, and thus set the bell *M* ringing, provided the key L^3 has been pushed over to the left contact: this test proves that the circuit closing arrangement in this mine is in good order: the shutter being lifted up as at *G*, the bell stops ringing: each mine may be separately tested in this manner. The bell circuit may also be tested without requiring the mines to be struck, by putting either of the terminals *T*, T^1, direct to earth, the switch plate *N*, *N* being plugged up.

3. The Firing Circuits.—One pole of the firing battery *I* is put to earth: the other pole is connected to the terminal T^3, in electrical connection with the switch plate *J*: the other switch plate *J* is connected to each of the springs H^2: if the switch *J*, *J*, is *unplugged* the firing battery is cut out of the main circuit.

For the automatic firing of either of the mines on being struck by a passing vessel, the switch plate *N*, *N* is plugged, and also the firing battery switch plate *J*, *J*, and each mine switch plate G^2, G^3, is also plugged up: the current from the signal battery *C* will then be passing through each of the shutter magnet coils and each mine system, but this current will be too weak to cause either of the armatures to be attracted: if, however, any one of the mines be struck by a passing vessel, that mine resistance will be cut out, and the armature of its shutter magnet attracted, thus dropping the shutter, and by reason of its metal blade G^x making contact between the springs H^1, H^2 belonging to it, the current of the firing battery *I* will be switched into the circuit of that mine through its fuze, and exploding the mine: the bell at the same time, by the act of the dropping shutter, continuing to ring.

Further, with the plugs in *N*, *J*, and in all of the mine switch plates, either of the mines could be fired "at will" by pressing back its shutter magnet armature, thus causing the shutter to fall, for which purpose knobs protruding through the front of the case are provided.

Any number of these shutters may be combined in one box.

McEvoy's Double Main Apparatus.—This system of Captain McEvoy's differs in one important respect from either of the foregoing, in that all the functions of firing, either "at will" or "automatically," L.XXVII.

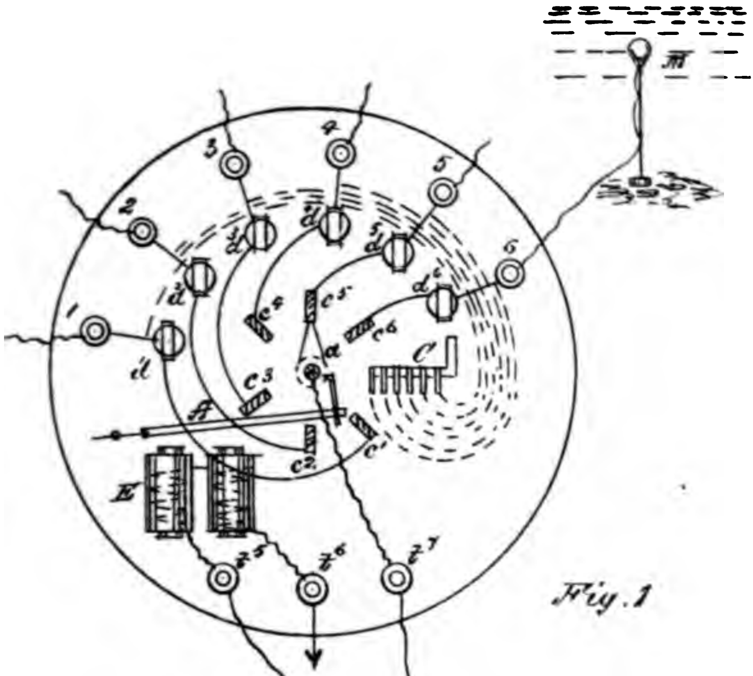


Fig. 1

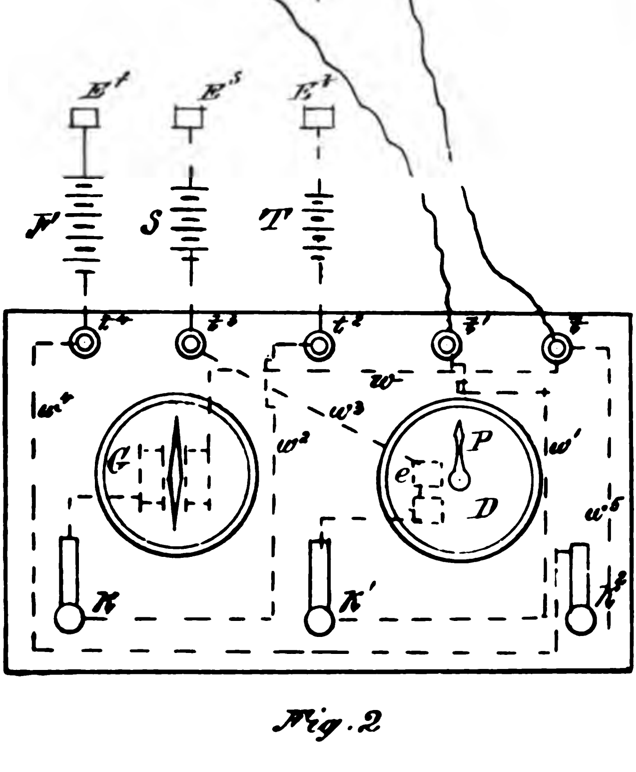


Fig. 2

signalling, and testing *any* number of mines can be performed by means of a double cored main cable between the mine station and the junction box, instead of requiring, as in the case of the previously described systems, a *separate* core for each individual mine, *i.e.* a *multiple* main cable; thereby a considerable economy is effected in the matter of cable.

This system consists of two instruments, one placed in the mine station, called the "shore" instrument, and the other placed in the junction box, and known as the "sea" instrument.

For use with "contact" mines, the "shore" instrument consists of a single shutter apparatus, an electric bell for signalling, a galvanometer, an index dial, and switching, testing, and firing keys, and the necessary battery terminals.

For use with "observation" mines only, the shutter apparatus and the signal bell are omitted.

The "sea" instrument is provided with a step by step arrangement, whereby each mine can be switched into the main circuit, and it also provides for all the mines being switched into the circuit at the same time: this instrument is also fitted with a disconnector for each mine.

In Pl. XXVII. at Fig. 2 is shown a plan of the shore instrument, and at Fig. 1 a general plan of the sea instrument.

In Fig. 2 G is the galvanometer: K the testing key: D the index dial marked with the number of each mine in the circuit, the pointer of which is moved by the action of the electro-magnetic step by step arrangement e: K^1 is the switching key: K^2 is the firing key: t and t^1 are the main cable terminals: T is the testing battery, and t^2 its terminal: S is the switching battery, and t^3 its terminal: F is the firing battery, and t^4 its terminal.

The "sea" instrument, Fig. 1, consists of the electro-magnetic step by step arrangement E: a the contact piece attached to and moving round with the ratchet wheel: $c^1, c^2 \ldots c^6$, the contact springs, one for each mine: $d^1, d^2 \ldots d^6$, the disconnectors, one for each mine: 1, 2, 3....6, the mine terminals: t^5 t^6, the terminals for the electro magnet-coil: C the main contact piece, M one of the six mines for which the apparatus here described is arranged for.

The circuits are as follows:—

1. **Switching Circuit.**—One pole of the switching battery S is put to

earth E^s, the other pole is connected to the terminal t^3 of the shore instrument: the wire w^3 connects t^3 to the coil of e, which is also connected to the key K^1: the contact piece of this key is connected by the wire w^1 to the main terminal t^1, then by one core of the main cable to terminal t^5 of the sea instrument: one end of the coil of the electro-magnet E is also connected to this terminal t^5, its other end being put to earth through the junction box at t^6: thus on pressing down the key K^1, the circuit from the switching battery is completed through the two electro-magnetic step by step instruments e and E in the shore and sea instruments respectively, and each depression of this key causes the dial pointer P and contact piece a to move on one step in unison, thus the position of the pointer P at the mine station indicates the position of the contact piece a in the sea instrument.

2. The Testing Circuit.—One pole of the testing battery T is put to earth E^t, the other pole being connected up to the terminal t^2, and by wire w^2 to the contact piece of the key K: the galvanometer G is connected to key K, and by wire w to the main terminal t: the second core of the main cable connects this terminal t of the shore instrument to the terminal t^7 of the sea instrument: a wire puts t^7 in electrical connection with the contact piece a of the sea step by step instrument: the wires from the six mines are led through their respective entrances in the junction box, and connected up to their respective terminals therein marked 1, 2....6, these wires being each to earth through their respective fuzes in the mines: these mine terminals are connected to one terminal of their respective disconnector fuzes, the other terminal of which is connected to its proper spring contact c^1, c^2....c^6; the main contact spring C is also connected up to the six mine terminals 1, 2.....6; thus on pressing down the testing key K, the current from the testing battery T will circulate through the galvanometer, causing its needle to be deflected, and through the whole of the six mine fuzes, if the contact piece a be in connection with the main contact spring C, or only through the particular mine fuze with whose contact spring c^1, c^2....c^6, the piece a may be switched on to: in the latter case the corresponding disconnector fuze will also be in the circuit: thus each mine may be tested separately, or all the mines at the same time: the deflections shown on the galvanometer affords evidence of the condition of the various mine circuits.

The Firing Circuit.—One pole of the firing battery F is put to earth

PL. XXVIII

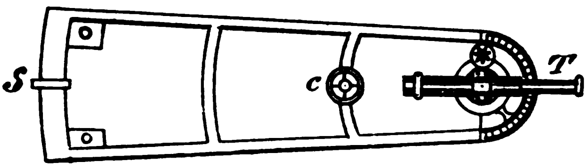


Fig. 1

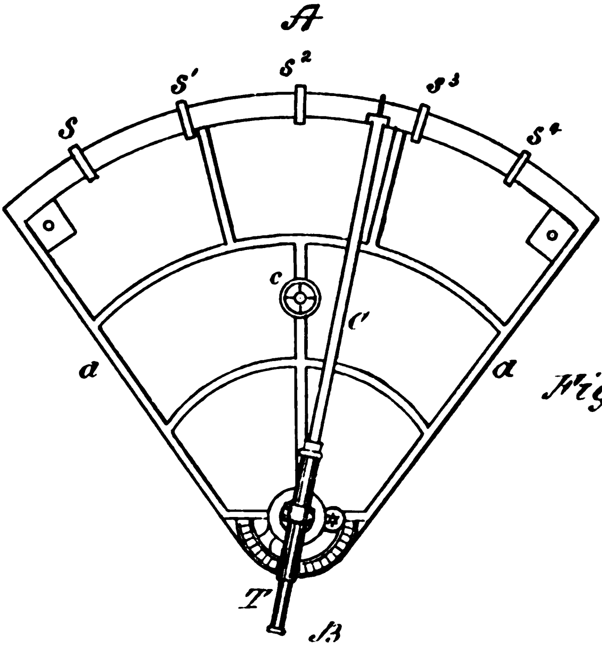


Fig. 2

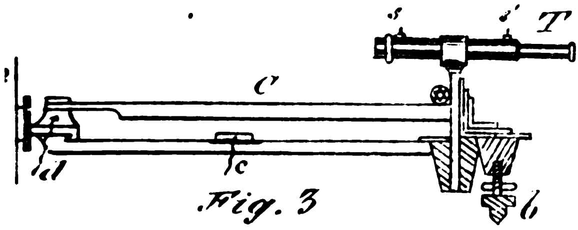


Fig. 3

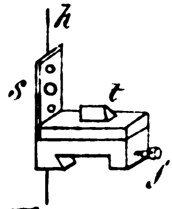


Fig. 4

E', the other being connected to the terminal t^4: a wire w^4 connects this terminal to the firing key K^2, and its contact piece by wire w^5 to the main terminal t: the firing circuit from the terminal t of the shore instrument through the sea instrument and the mines is then the same as in the case of the testing circuit; thus on pressing down the firing key F, either the whole six mines are fired, or only one of them, depending upon the position of the contact piece a in the sea instrument: in the case of one mine only being fired, its circuit is insulated by the rupture of its disconnector fuze.

The apparatus here described is designed for use with a set of six mines intended to be fired by *observation*, but if it be required for use in connection with contact-mines, it would be only necessary to introduce a single shutter apparatus (similar to that described on page 106) in the firing circuit of the shore instrument.

The Intersectional Arc Instruments.—These instruments are used in connection with the "observation" method of firing submarine mines, and are required for the purpose of enabling any mine to be exploded at the actual moment of a hostile vessel being directly over it, when attempting to pass through a mine "field."

Two kinds of intersectional arcs are employed, known as the "firing" arc and the "converging" arc.

In Pl. XXVIII., at Fig. 2, is shown a plan, and at Fig. 3 a section through $A\ B$ of the "firing" arc: Fig. 4 is an enlarged view of one of the front sights: and Fig. 1 a plan of the "converging" arc.

The "firing" arc, Fig. 2, consists of a cast-iron frame a, with three feet, as b, Fig. 3, provided with levelling screws: c is a circular spirit-level: T is a telescope fitted with one horizontal and three vertical cross wires, and mounted so as to permit of its being raised and lowered by means of screw gearing, and also of lateral movement round the upright, to which it is attached, as a centre: a clamping screw is provided to fix the telescope in any desired position; s, s^1 are sights fixed on to the telescope in a vertical plane passing through its axis: C is a brass tube extending from the telescope upright, to which it is rigidly attached, to the inside of the outer rim of the instrument, and d, Fig. 3, is a brass spring projection fixed to and insulated from the tube C: this outer rim of the firing arc is provided with sights, $S, S^1 \ldots S^5$, corresponding to the number of the mines controlled by it. The form of the sight is shown in Fig. 3, where t is the contact piece:

f, the binding screw: and *h* a thin wire for giving the alignment of the mine.

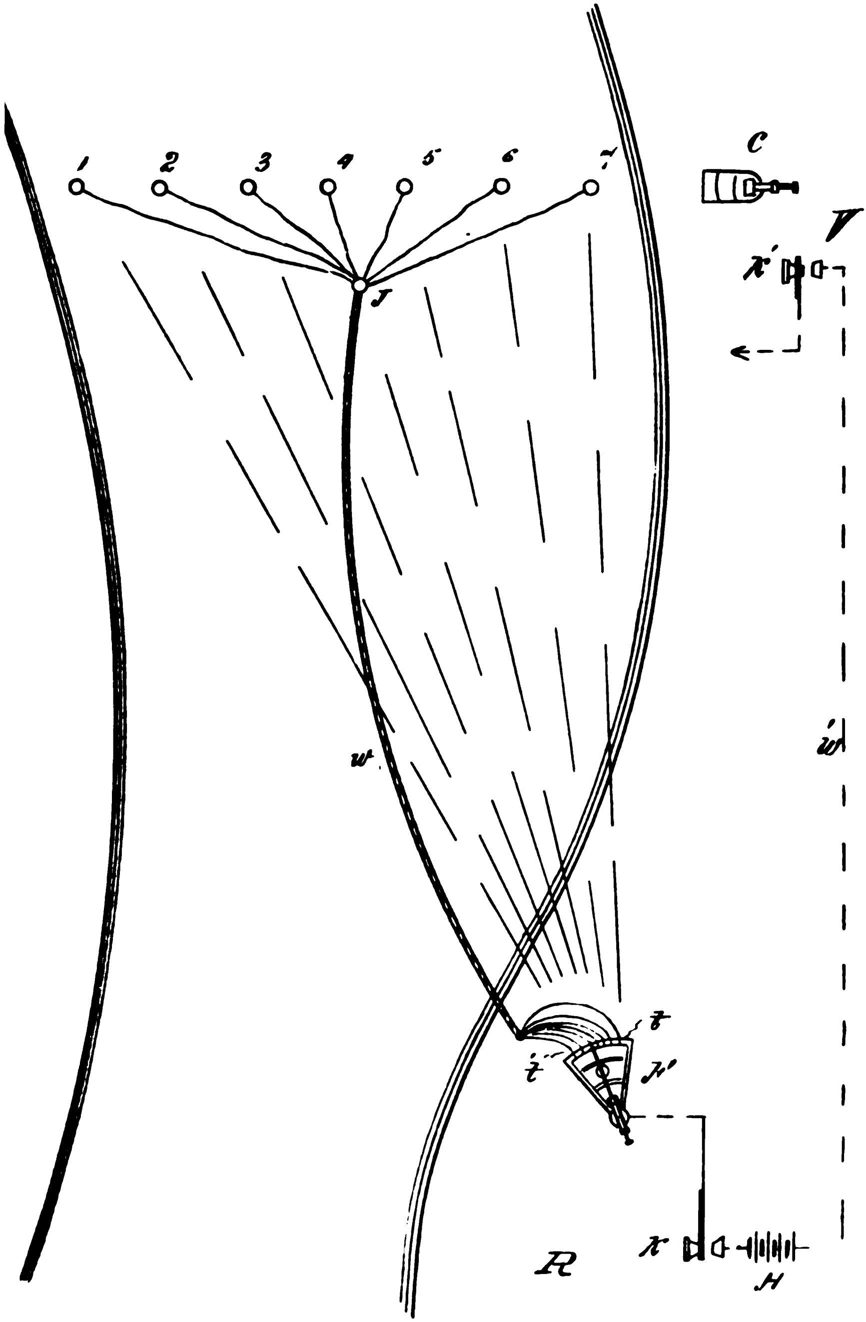
The Converging Arc.—The "converging" arc, shown at Fig. 1, is precisely similar in construction to the firing arc, with the exception of there being no brass tube in connection with the telescope, and only one sight.

The Manipulation of the Intersectional Arc Instrument used alone.— A simple mode of using these instruments in connection with mines intended for observation firing only is shown in Pl. XXIX., where *F* is a "firing" arc, *H* the firing battery, and *K* a firing key, placed at the mine station *R*: *C* is a "converging" arc, and K^1 a firing key placed at the station *V*: *w'* is the electric wire connecting these two arcs together: 1, 2.....7, submarine mines: *w* the multiple cable between the firing arc and the mines; and *J* the junction box.

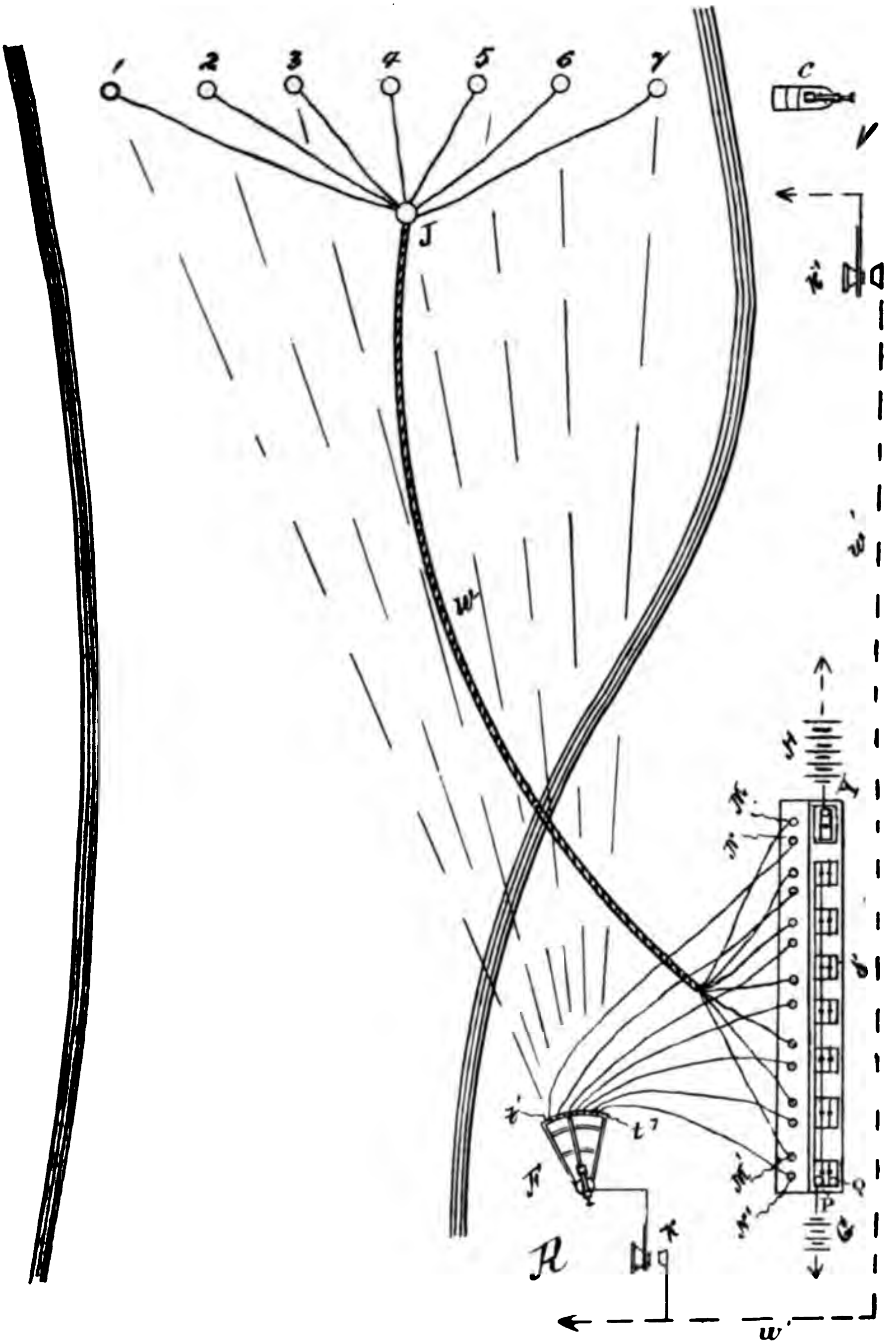
The circuit is as follows: one pole of the firing battery, *H* is joined to the wire *w'*, connecting the two stations, the other pole to the key *K*: the other end of the wire *w'*, at station *V*, is attached to the contact piece of the key K^1, the other part being put to earth: the seven mines are connected by the shore ends of the multiple cable *w* to the seven sights respectively of the firing arc *F*: the sliding bar is connected by means of an insulated wire passing through the tube to the key *K*. Thus with the mine fuzes to earth, the firing battery circuit is completed, when the sliding bar is resting in contact with either of the contacts $t^1 \ldots t^7$, &c., both of the keys *K* and K^1 being pressed down at the same time; this can only happen when a vessel attempting to pass the mines 1....7 is on the line of the mines, and exactly over one of them at the same time; the former position would be known to the operator at station *V* by means of the telescope of the converging arc *C*, who would press his key K^1 down, and the latter position to the operator at station *R* by means of the telescope of the firing arc *F*, who would also press his key *K* down.

In Combination with the Service Shutter Apparatus. First Method.— One method of using the telescopic intersectional arc instruments in connection with the Siemens or service shutter apparatus, when the firing and converging arcs are in electrical circuit with one another, is shown in Pl. XXX. *S* is the shutter instrument, and *F* the firing arc placed at the station *R*: *C* the converging arc at the station *V*: 1, 2....7 the mines connected up to the main cable *w* in the junction

PL.XXIX



PL. XXX



box J, the other ends of the seven cores of this multiple cable being led to the terminals M, M^1, &c., on the top of the shutter apparatus: the seven terminals $t^1 \ldots t^7$ of the firing arc F are led to the seven terminals $N \ldots N^1$ respectively of the shutter apparatus: one pole of the key K is connected to the movable contact bar of the firing arc F, and the other pole of this key to one end of the cable w': the other end of this cable is attached to one pole of the key K^1 at station V, the other pole of this key being put to earth. From this description of the connections and leads it will be seen that if a plug be inserted between P and Q, the signalling battery G current will flow through all the mines by the cable w, but not through the firing arc so long as both, or either of the keys K, K^1 be open, *i.e.* not pressed down; if however the sliding bar of the firing arc be moved on to either of the contacts $t^1 \ldots t^7$, for instance to t^4, and both K and K^1 be pressed down at the same time, the current from the signalling battery passing through the shutter apparatus of that particular mine will become strong enough, by reason of the circuit closer resistance being cut out, to attract its armature, causing its shutter to fall and bell to ring, and if the firing battery plug has been previously inserted at Y, the mine No. 4 will be exploded: or if this firing battery plug be not inserted on the shutter falling, the operator has then the option of firing the mine by inserting it or of leaving it unexploded.

By this method of connecting up the two arcs, it is necessary for both the keys K and K^1 to be pressed down, and the sliding bar of the firing arc to be in contact with one or other of the contacts $t^1 \ldots t^7$ at the same moment to explode the mine in connection therewith. To effect the explosion of either of the mines at any desired moment, when a ship may *not* be on the line of mines, it would be first necessary to signal the observer at V to close his key; the connecting up of these arcs may however be arranged so as to permit of the firing of either of the mines on the closing of the key K only.

Second Method.—This method is shown in Pl. XXXI., where the converging arc key K^1 is in simple circuit with an electric bell B, the ringing of which indicates to the observer at R the fact of a ship being on the line of the mines: the key K of the firing arc F is in this case put direct to earth, and therefore either of the mines may be exploded, or only its shutter dropped by the observer at R pressing down his key, and without the intervention of the observer at the distant station V.

In the event of more than one line of mines being laid down, and therefore more than one converging arc used, a special arrangement for denoting on which particular line of mines a ship might be would have to be devised, as for instance a different sounding bell for each line, or one ring of a bell for No. 1 line, two rings for No. 2, and so on, or a rheotome or step by step recording instrument.

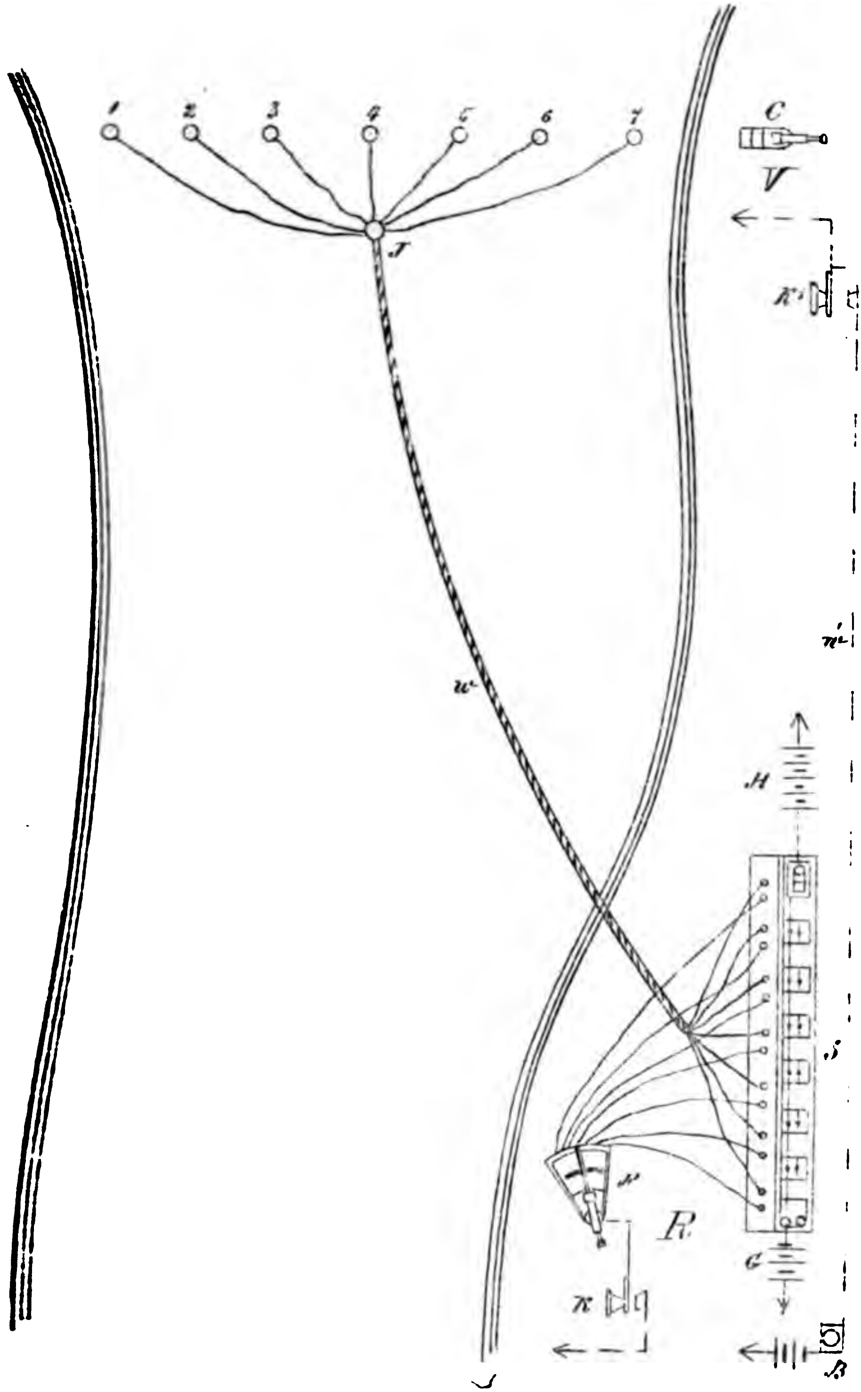
Method of using Two Firing Arcs.—It may not be desirable to place a distant observing station on the line of the mines, but instead to place the second observing station on the opposite bank of the river as at V, in Pl. XXXII., in which case it will be necessary to use a second firing arc instrument at V, and a series of keys, *i.e.* one key for each mine at the station R, and to connect these two arcs F, F^1 by means of a multiple cable w^1. The seven cores of the cable w^1 are connected at the station V to the respective contacts t . . . . t^1, and at station R to one pole respectively of each key K, the other poles of which are all connected up to the firing arc F by the single wire w^2. Then if a ship be on alignment with No. 4 mine at V, the observer there presses down his key K^1, and if at the same instant she is on alignment with No. 4 mine at R, the observer there presses down key 4, and explodes that mine with the ship directly over it.

The Siemens Distance Measurer.—The Siemens Distance Measurer is another method of ascertaining at any moment the relative position of a ship attempting to pass over a mine field, and any of the mines therein, and is in some respects an improvement on the telescopic arc arrangements before described, as will be seen from the following description of the various forms of this apparatus.

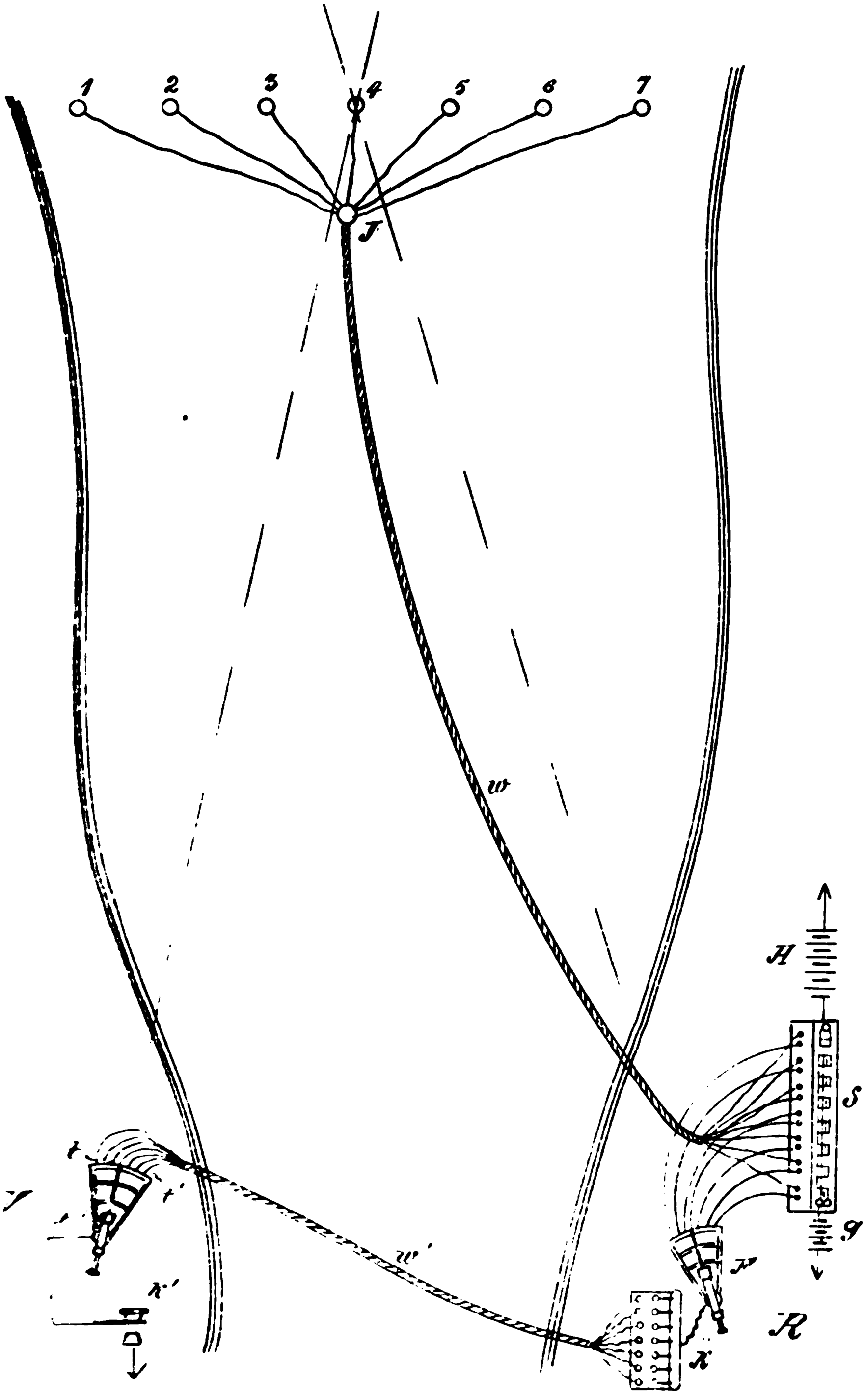
The principle on which this Siemens Distance Measurer is constructed is shown in Pl. XXXIII. at Figs. 1, 2, and 4.

Let o (fig. 1) represent the position of an object, for instance the mainmast of a vessel, which can be observed from two points B^1, B^2, by means of the telescopes T^1, T^2, each capable of being turned round a vertical axis at the points B^1, B^2. An indicator fig. 3, carrying two pointers p, p^1, each movable round a vertical axis at b^1, b^2, is fixed at any suitable place. In the normal position, the optical axis of each telescope T^1, T^2 is at a right angle to the base line $B^1 B^2$, which may be termed the "large" base line, $b^1 b^2$ being called the "small" base line.

PL. XXXI.



PL. XXXII



When either of the telescopes is directed towards the object, the corresponding pointer p, or p^1 is, by means of electrical transmission of power, moved through the same angle. The point of intersection o of the two pointers p, p^1, form then with the points b^1, b^2 a triangle $o\ b^1\ b^2$, similar to the large triangle $O\ B^1\ B^2$, and the length of each base line B and b being known, the distance of the object O can be calculated. For instance, let B be the length of the "observing" or "large" base line $B^1\ B^2$, and b of the "indicator" or "small" base line $b^1\ b^2$, then the distance X between B^1 and the object o, is $X = \frac{B}{b} x$, where x is length $b^1\ o$ on the indicator.

If the position of each telescope is a permanent one, the pointers p, p^1 can be suitably graduated, and the distance read off direct at their point of intersection.

If a map of the mine field to be observed is prepared to a scale having the ratio $b : B$, so that b^1, b^2 represent on the map the actual points B^1, B^2 of the observing telescopes T^1, T^2, then the intersection of the pointers p, p^1 gives at once on this map the exact position of the ship.

As the motion of the telescopes when following a moving ship is transmitted electrically to the pointers of the indicator, they (the pointers) always remain parallel with the telescopes whatever the position of the latter may be, consequently the varying points of intersection of these pointers describes on the map the route of the ship.

The indicator can be fixed in any desired position.

Pl. XXXIII., Fig. 3, shows in plan the distance measurer arranged with two separate observing stations.

In Pl. XXXIV., Fig. 2, a different arrangement of the apparatus is represented. The indicator is here transferred to B^2, so that the centre of motion of the telescope T^2, and pointer p^2 is identical, the short base line $b^1\ b^2$ forming part of the large one B^1, B^2. The principle of the apparatus, however, remains the same, the only difference being that one of the separate observing stations and its electrical communication with the indicator are dispensed with. This arrangement is adopted when it is found that one of the observing stations is likewise a suitable position for placing the indicator at. It is immaterial whether the indicator is placed to the right or left of the base line.

I 2

The telescopes are directed to the object (moved to the right or left) by turning a handle, which sets in motion toothed gearing in connection with an endless screw and toothed segment to which the telescope is fixed. The same motion of the handle causes the armature of a magneto-electric inductor to revolve, thereby sending a succession of alternate currents either into line I. or II., Fig. 3. A special contact arrangement fixed on the spindle of the armature makes connection with line I. or II. according to the direction in which the handle is turned. Each line is connected at the indicator with an electro-magnet, the polarized tongue of which has fixed to it an escapement that actuates a ratchet wheel. The escapements and ratchet wheels (one set to each electro-magnet) act on an endless screw and toothed segment carrying a pointer by means of planet gear so arranged that the pointer moves to the right or left, according as one or other of the electro-magnets has been actuated by the currents from the observing station, these currents being directed into lines I. or II., as before mentioned, when the handle of the indicator is turned either forwards or backwards. In the apparatus arranged with two observing stations, Pl. XXXIII., Fig. 3, it is seen that each pointer is acted upon by a separate inductor, the movement of the pointer to the right or left being accordant with that of the telescope, and effected in the manner previously described.

PL. XXXIII.

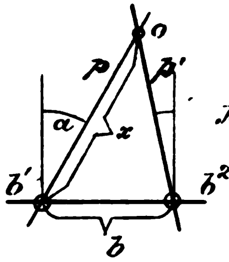


Fig. 2

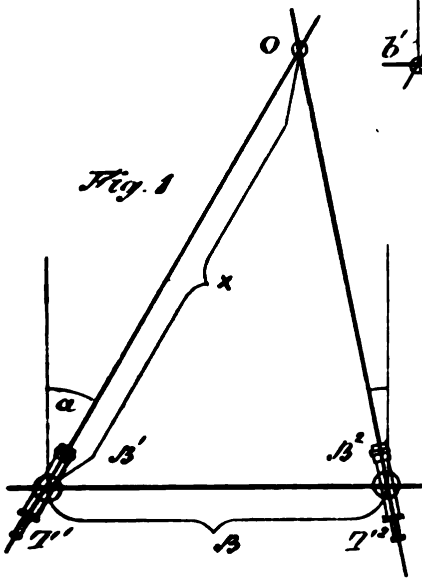


Fig. 1

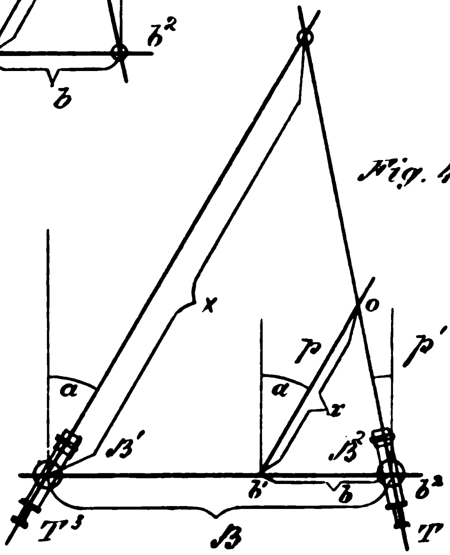


Fig. 4

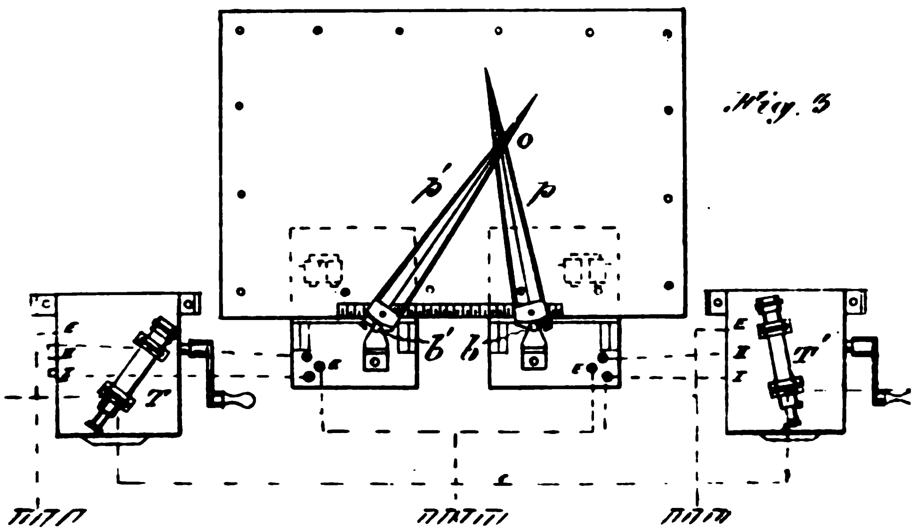
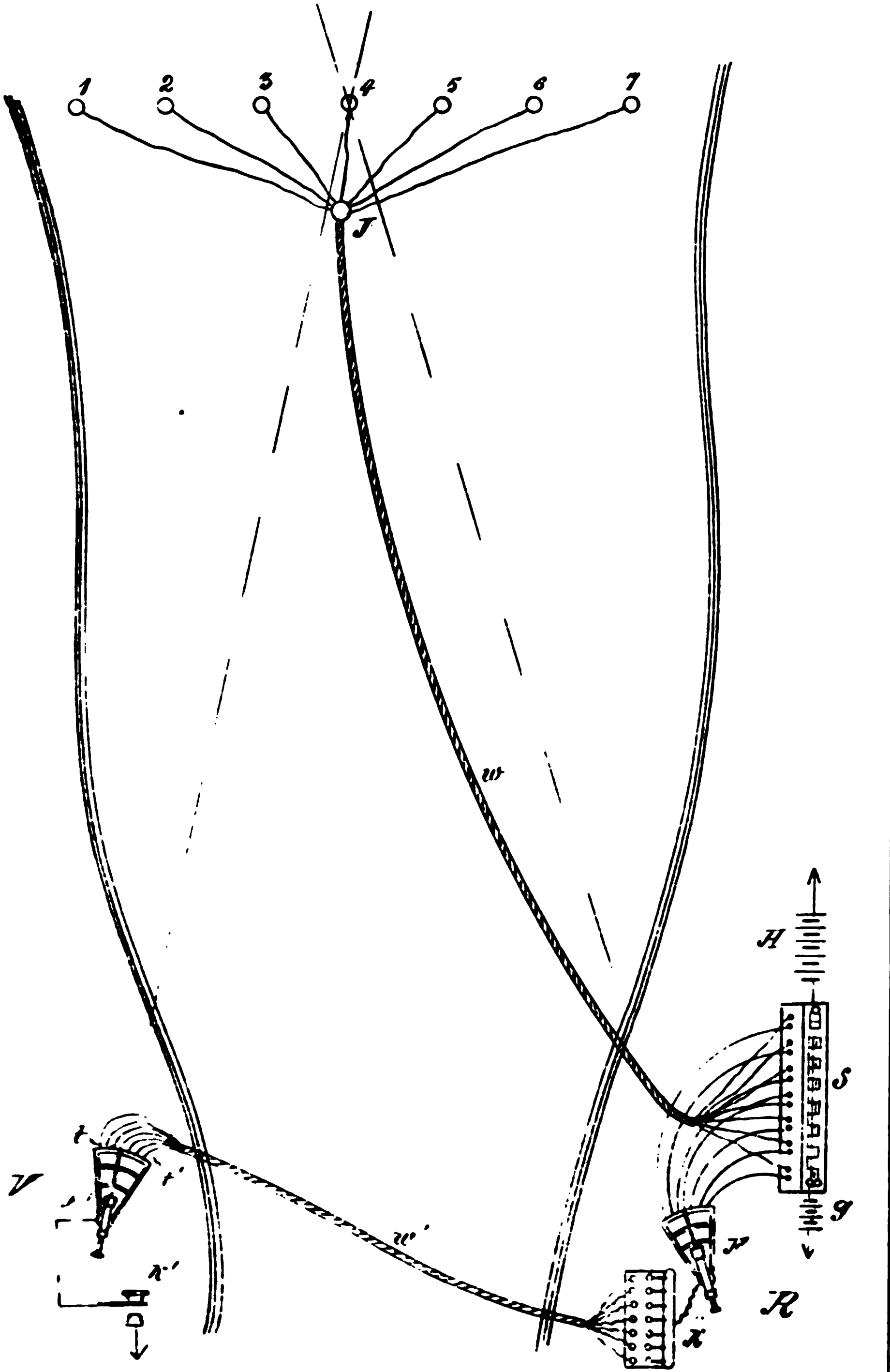


Fig. 3

PL.XXXII



CHAPTER VI.

TESTING.

1. Necessity for Careful Testing—2. Nature of Tests—A, Mechanical Testing—3. Mine Cases — 4. Junction and Connecting Boxes — 5. Mooring Chains — 6. Anchors — 7. Circuit-closers — 8. Mechanical Joints and Disconnectors — 9. Electrical Cables — 10. The Firing Apparatus of Mechanical Self-acting Mines—11. Shutter Apparatus—B, Electrical Testing — 12. The Test Table — 13. Sea-cell Testing — 14. Station Test Table—15. Electrical Cables for Insulation Resistance—16. For Copper Resistance—17. For Continuity—18. Testing Electrical Joints for Insulation Resistance—19. For Continuity—20. Testing Earth Circuits for Resistance—21. Testing Fuses—22. For Efficiency—23. Testing Disconnector Fuses for Resistance and Efficiency—24. Testing Batteries for E. M. F.—25. For Internal Resistance—26. Testing Firing Batteries for Power — 27. Testing the Directive Instruments — 28. Testing the whole System — 29. Accidents in Mine Circuits.

NECESSITY for Careful Testing.—Testing is a most important branch of the work connected with the operation of submarine mining, as the greater portion of the material constituting a system of submarine mines has to be submerged at a more or less considerable depth below the surface of the water for long periods of time, when it is subjected to a pressure of an intensity proportionate to the depth, and which is sure sooner or later to find out any weak points in the system. Further, all buoyant mines are subject to constant movement, due to the action of the sea in bad weather, and currents, tides, &c., causing considerable wear and tear to the mooring chains, and to the electrical cables between the shore and the junction box, and between the mine and the junction box.

It is thus absolutely necessary that every detail in connection with a submarine mine be submitted to the most careful and searching tests, according to its liability to be affected by continued submersion.

Nature of Tests.—The tests which must be applied to a system of submarine mines are of two kinds, viz. A, Mechanical, B, Electrical, and the object of instituting them is to secure as far as is practicable absolute certainty of action of any one mine at any desired moment, no matter how long a period of time, or at how great a depth it may have been submerged.

Each kind of mine has its own special set of tests apart from those which are either common to all, or any particular class of submarine mines; thus, for instance, the test for mine cases and moorings differ only in degree for all classes and types of mines, whether self-acting, controlled, buoyant or ground; while the tests for fuzes are similar, whether for self-acting or controlled mines.

A.—MECHANICAL TESTING.

Mechanical Testing.—The mechanical testing of a system of submarine mines includes the following operations:—

1. Testing mine cases for strength.
2. „ „ „ water-tightness.
3. „ junction and connecting boxes for strength.
4. „ mooring chains and wire ropes for strength.
5. „ anchors or sinkers for holding power.
6. „ circuit-closers for water-tightness.
7. „ mechanical joints for water-tightness.
8. „ electric cables for tensile strength.
9. „ the firing apparatus of mechanical self-acting mines.
10. „ „ shutter apparatus.

Mine Cases.—The mine case requires to be tested as to its capability to resist leakage, and to withstand external pressure consequent on the depth below the surface at which it is intended to moor it; and to secure the necessary margin of safety the mine case should be submitted to a greater pressure during these tests than it would be subjected to on actual service.

The water-tightness of the mine case can best be ascertained by submitting it to an internal water pressure by means of a forcing pump and pressure gauge, as by this method the position of any leak can be at once discovered, and if possible stopped afterwards, when the test would have to be repeated; if this test be made by mooring the mine case at the required depth, it would be difficult to discover the position of a leak should one occur.

In making this test the mine case should have its electric cable fitted so that any leakage at the gland may be discovered and corrected.

The strength of the mine case to resist external pressure can only be tested by mooring it at the required depth below the surface of the water.

Junction and Connecting Boxes.—Junction and connecting boxes would be tested for strength to resist compression in the same manner as described for the mine cases.

Mooring Chains and Wire Ropes.—The chains or wire ropes to be used for mooring the mines would have to be tested for tensile strength, and this test would be carried out at the place of manufacture under official supervision.

Anchors or Sinkers.—The only practicable method of testing the efficiency of mine anchors or sinkers is to moor a buoyant mine to an anchor, which is theoretically considered correct as to form and weight for that size of mine, choosing a position that will expose the mine, thus moored, to strong tides and rough water. This test will also prove the efficacy of the mooring chains as well as the anchor for maintaining the mine in position. To make this test a thorough one, the mine should have a considerably greater *reserve* buoyancy than it would be provided with on actual service.

Circuit-closers.—It is most essential that the circuit-closer *cover* should be water-tight, where it screws on to the base of the circuit-closer, and at the gland where the cable enters, and therefore it should be tested for water-tightness by buoying it at the required distance below the surface of the water, having previously fitted it with its cable.

Mechanical Joints and Disconnectors.—Mechanical joints and disconnectors must also be tested for water-tightness, and this operation may be carried out when testing the junction boxes for strength, by fitting the joints and disconnectors up as for service, and placing them in their respective junction boxes.

Great care must be exercised in making these joints absolutely impervious to water leakage in actual work, as a leak at these points may very seriously affect the efficiency of the mine circuit it is on.

Electrical Cables.—Electrical cables require to be tested (mechanically) for tensile strength, which test would be carried out in the ordinary manner at the place of manufacture.

The Firing Apparatus of Mechanical Self-acting Mines.—The only satisfactory manner by which to prove the efficiency of the firing apparatus of a *mechanical* self-acting mine, whether it be provided with chemical or percussion fuzes fired by direct contact or by the interposition of a falling weight, is to fit the mine up complete for service with the exception of the explosive charge, moor it in a suitable position, and then cause it to be subjected to every kind of collision with a vessel that might occur on actual service—as, for instance, causing the mine to be struck by a vessel proceeding at various rates of speed, and also by merely allowing the vessel to drift against the mine. On the completion of each test the mine should be lifted, and the state of the firing apparatus carefully examined.

In the case of a self-acting mine on the "Singer" principle of a falling weight, the strength of the safety pin to support the accidental falling of the weight should be proved; also the capability of the weight to remain in its seating with the mine in a position where it is subjected to a considerable motion of the water—in fact that nothing short of a blow or push from a colliding vessel, when the mine is once moored, can cause the weight to fall out of its seating.

Shutter Apparatus.—The shutter apparatus must be submitted to a mechanical test to prove the capability of its armature to prevent the shutter from falling by the concussion of a heavy gun fired in near proximity to it, in the event of a mine station being located in a fort.

B.—ELECTRICAL TESTING.

The electrical testing of a system of submarine mines is a very important work, and the efficiency of the mine defence in a time of need will depend in a great measure on the amount of care exercised in making these tests, and the thoroughness with which they are carried out; and more especially is this the case with *electrical* self-acting mines, as when once placed in position any fault in their system cannot be ascertained; while, though in the case of a system of *controlled* mines a weak spot in the circuit of any one mine can be discovered, yet to remedy the defect is a somewhat laborious operation, and besides occupies a considerable time which may not be available when required.

Electrical testing consists of the following operations:—

1. Testing electrical cables for insulation resistance.
2. " " " copper resistance.

3. Testing electrical cables for continuity.
4. „ joints for insulation resistance.
5. „ „ continuity.
6. „ earth circuits for resistance.
7. „ fuzes for resistance.
8. „ „ efficiency.
9. „ disconnector fuzes for resistance.
10. „ „ „ „ efficiency.
11. „ batteries for E. M. F.
12. „ „ internal resistance.
13. „ firing batteries for power.
14. „ directive instruments.
15. „ whole system.

The Test Table.—A test table is merely a combination of the various instruments required for the making of the different tests, on one base, for the purpose of facilitating the operations.

As only a rough indication of the condition of the electrical system is required in submarine mining on actual service, such as will guarantee its efficient working at the proper moment, the very simplest tests will suffice at the mine stations; the more elaborate and delicate tests will have to be instituted at the submarine depôt from which all the material is sent out in perfect condition to the various stations.

If at any time a fault be discovered by the operator at a mine station in any mine circuit sufficiently serious to operate against its action—such, for instance, as a short circuit, or a break in the circuit, either of which would prevent the mine being exploded, and which might occur either in the core of the main cable, or in the junction box, or in the mine cable, or in the circuit-closer, or in the fuze—it would then no doubt be most interesting to be able to localise the position, and discover the nature of the fault; but for all practical purposes in time of war the mine on the faulty circuit would have to be cut out of the system until such time as an opportunity occurred for replacing it.

In Pl. XXXV., Fig. 1, is shown the plan of a test table as constructed by Messrs. Siemens Bros., and which has hitherto been generally used in connection with a system of submarine mines.

A is the table or board on which the following instruments and terminals are fixed:—

B Wheatstone bridge and resistance box.

C Thermal galvanometer and 100-ohm resistance box.

D Three-coil galvanometer.

E Battery commutator.

G Astatic galvanometer.

H Safety firing key.

I Firing-battery terminals.

K, L, M Terminals for wandering leads.

Terminals, 1.—Zinc earth for signalling battery.
„ 2.—Copper earth.
„ 3.—Carbon „
„ 4.—Zinc „
„ 5. „ „ for depolarising battery.
„ 6. „ „ „ test battery.
„ 7.—Copper „ „ firing battery.

Batteries:—*f* firing battery.
t testing battery.
s signalling battery.
d depolarising battery.

S Commutator of shutter apparatus.

As will be seen from the figure, this is an exceedingly complicated form of test table, due principally to the employment of the "sea-cell" test method for ascertaining the condition of the mine circuit. The arrangement of the connections as shown in Fig. 1 is not an arbitrary one, but may be varied to suit the operator.

Sea-cell Testing.—In Pl. XXXV., Fig. 2, is shown a diagrammatic plan of the "sea-cell" method of testing in connection with a buoyant mine with separate circuit-closer case.

w is the main cable leading from galvanometer *G* to the mine *M*, through its fuze *f* to copper earth *g*; *w'* is the cable branching from main cable to the circuit-closer case *C* through its 1000 ohms resistance to zinc earth *h*; *e* is zinc earth plate inside the mine, between the fuze and the galvanometer; *a, b, d,* are zinc, copper, and carbon earth plates connected up to galvanometer *G*, a key being provided for each one, PL. XXXV.

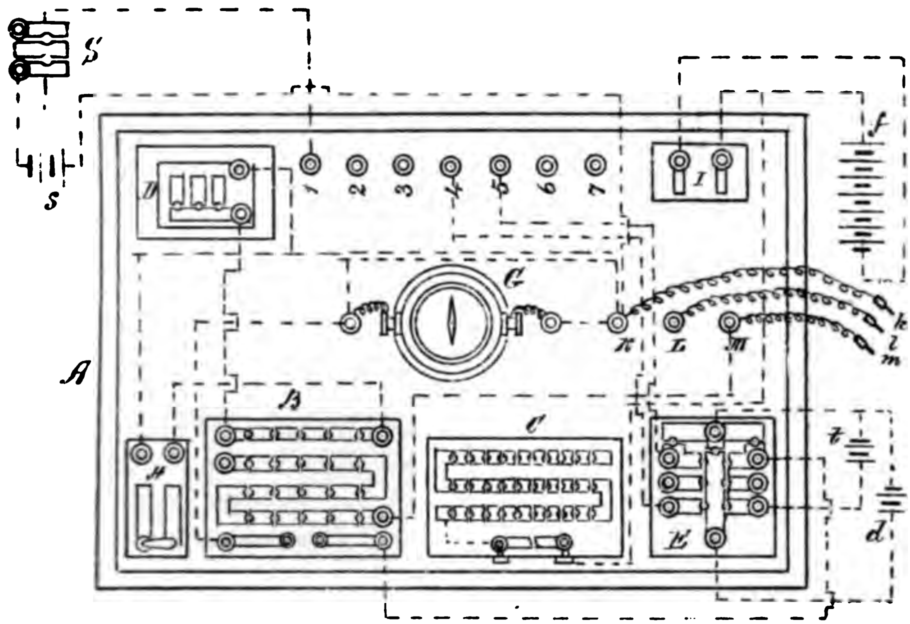


Fig. 1

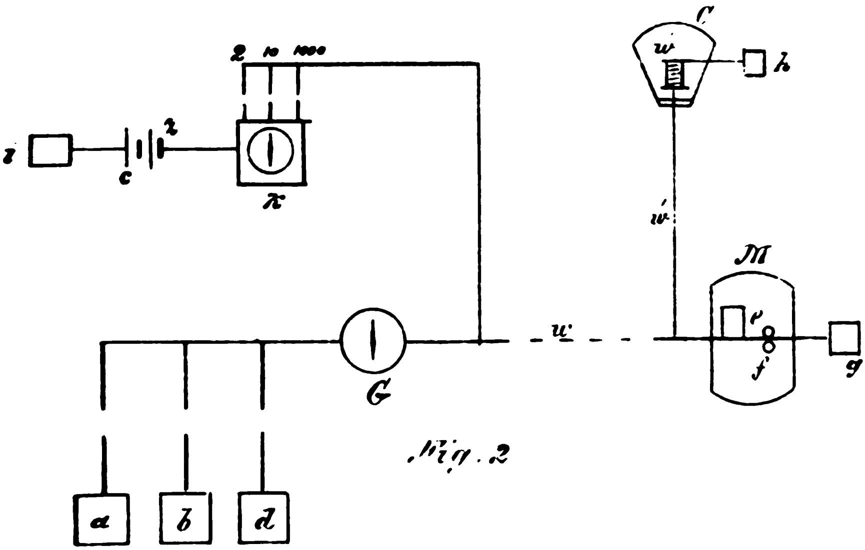


Fig. 2

so that the circuit of either of these home earths with the galvanometer may be closed at will.

The zinc plate *e* in the mine is only put to earth on water finding access to the mine.

With the system in good condition a set of deflections are obtained with the galvanometer *G* by the sea-cell set up between the different "home" and "out" earths, which are carefully recorded: then on any accident occurring to the system a different set of deflections will be obtained, the nature of the difference indicating the nature of the accident.

For instance, with the system in good order, on closing of key *b*, a sea-cell will be found between the circuit-closer case zinc earth *h*, through the 1000 ohms resistance, and the copper earth *b* at home, which will be represented by a certain deflection on the galvanometer *G*; but suppose the mine zinc plate *e* to be put to earth by the mine case leaking, then the sea-cell will be formed between *b* at home and *e* in the mine, as well as between *b* and *h*, but the resistance of the former being less than the latter by some 1000 ohms a different deflection will be given on the galvanometer to what was originally obtained sufficient to indicate the access of water to the mine.

The nature of this method of testing is however too delicate, and too likely to be interfered with by earth currents, and by extraneous causes, such as the sheathing of the multiple cable becoming an extra earth, &c., that it cannot be implicitly relied upon, or at least not sufficiently so to make up for its complexity.

Station Test Table.—The station test table, a plan of which is shown in Pl. XXXVI., Fig. 1, is a slight modification of the portable test table designed by the Torpedo Department of the Telegraph Works Company at Silvertown; it differs from the service test table previously described, in the elimination of all the terminals, 1 to 8 inclusive, the three-coil galvanometer *D*, the battery commutator *E*, firing key *H*, and terminals *I*; while it differs from the Silvertown portable test table in the form of the Wheatstone's bridge, and the arrangement of a single "double contact" key instead of two separate keys. This test table is intended for mine station testing, hence its name.

The instruments consist of a P. O. Wheatstone's bridge with resistance coils *B* and double contact key *F*; a thermal galvanometer with resistance coils *C*; a *sensitive horizontal* astatic galvanometer *G*; and two terminal plates *D, E,* provided with two wandering plug leads *J, K.* The whole of these instruments are mounted on a polished teak board *A*, contained in a polished teak box.

The Wheatstone bridge *B* is fitted with ratio coils of 10, 100, and 1000 ohms, enabling the ratio to be adjusted to 10 to 100, or 10 to 1000, or 100 to 10, or 1000 to 10, as required. The resistance box of the bridge *B* is fitted with coils of from 1 to 4000 ohms, the total amount of resistance being 11,110 ohms, allowing with a proper ratio the measurement of resistances ranging between the extreme limits of 0·01 ohm and 1,111,000 ohms.

The firing battery resistance coils *C* are graduated from $\frac{1}{20}$ ohm to 100 ohms, ascending by the fraction of $\frac{1}{20}$ ohm.

The astatic galvanometer *G* has a resistance of 1000 ohms.

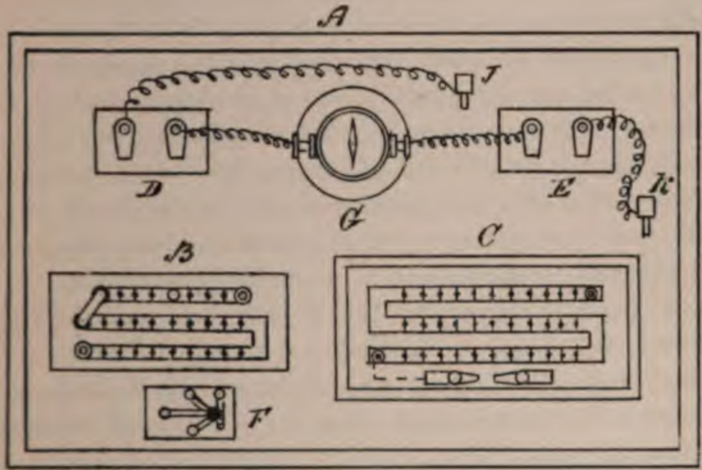
Electrical Cables for Insulation Resistance.—The electrical cables provided for a system of submarine mine defence are delivered to the various mine stations in good condition, and a record of the tests made with them at the depôt both for insulation and copper resistance, per knot, mile, or other length, will accompany each drum, so that it will rarely be necessary for the operator at the station to test them, except for insulation and continuity. But it may be that under special circumstances mines will have to be laid down with cables whose electrical condition is unknown, in which case the operator by means of the station test table will be in a position to measure the insulation and the copper resistance of the unknown cable he will have to work with.

For testing the insulation resistance of a cable the following connections are made, as shown in Pl. XXXVI., Fig. 2: the drum of the cable is either lowered into the water from a crane, or placed in a tank *A*, keeping both ends out and quite dry: one end of the cable is then connected to terminal *c* of the bridge; the pole of the battery is then put to earth.

The insulation resistance of a knot of cable in perfect condition is as high as 1000 meg-ohms, and as the capacity of the bridge *B* is only about 1 meg-ohm, it is therefore only possible to obtain an approximate measurement of the internal resistance of such a cable by this means. In actual practice a cable having anything over an insulation resistance of 1000 ohms will be sufficient for proper working, though the higher this measurement is the more efficient is the cable for submarine work.

PL. XXXVI

Fig. 1



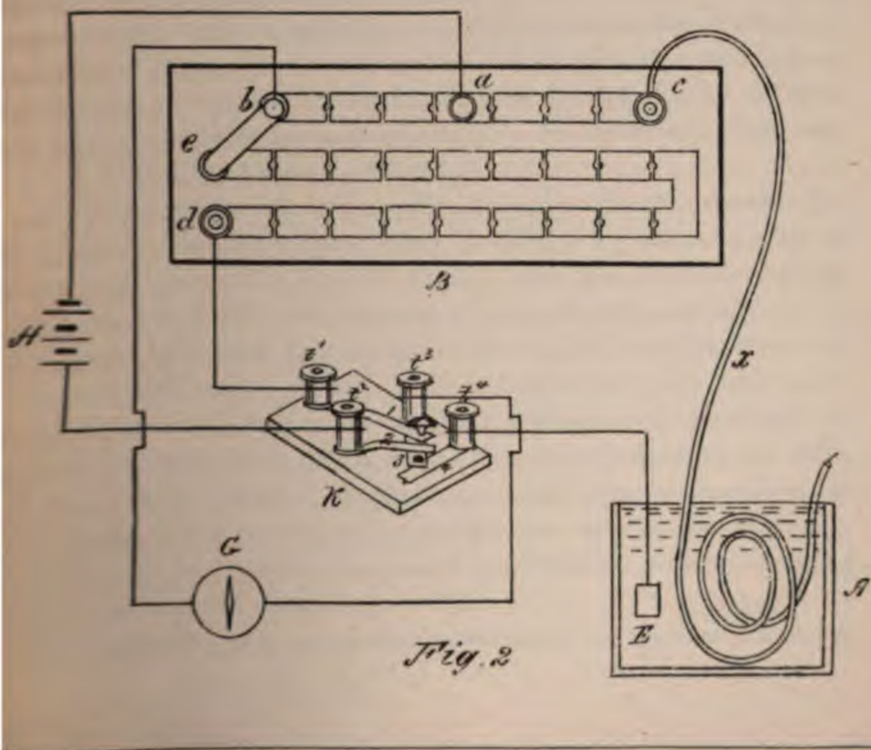


Fig. 2

Then to make the test unplug all the resistances in *a c*, equal to 1110 ohms, and the 10-ohm resistance in *a b*, and also unplug all the resistances in *e d*, 1 to 5000 ohms inclusive, equal to 10,000 ohms; then press key 1 into contact with key 2, by which the battery current is sent through the four arms of the bridge; and by still further pressing the key down contact is made with key 3, completing the galvanometer circuit; note the direction of the deflection of the galvanometer needle, whether to the right or to the left, if there be any. If no deflection of the needle occurs on pressing down the keys, then the resistances unplugged is a measure, in the proportion of 10 to 1110, or 1 to 111 of the *insulation* resistance of the cable being tested, giving the actual resistance of 10,000 × 111 or 1,110,000 ohms. If the galvanometer needle be, however, deflected to the left for instance, depending upon how the connections are made, it will show that the actual insulation resistance of the cable under test is higher than the bridge is capable of measuring: if on the other hand the needle is deflected to the right, then it shows that the insulation resistance of this cable is less than 1,110,000 ohms, and in this case the proportion *a b* : *a c*, must be altered, or some of the measuring resistances plugged until, on pressing down the keys, no deflection of the galvanometer needle is caused, or in other words a balance is obtained. It will save much time in testing if a definite plan of connecting up the battery be used, and a record made as to the meaning of the right and left swing of the galvanometer needle: for instance, in this case, left "too little," and right "too much."

A simple test for insulation, when it is not required to measure the *amount*, can be made without using the bridge by connecting up, as shown in diagram Pl. XXXVII., Fig. 1. Note the deflection on (1000 ohms) *G*, if any, and then connect *a* to *b*, and note reading. If the latter be at least twice as much as the former, the insulation resistance is at least 1000 ohms. Should any considerable deflection occur before *a* was joined to *b*, this would denote a defect in the insulation, the position of which could be discovered by gradually drawing the cable out of the tank. If the fault existed at a single point, the needle would swing back at the moment of that point of the cable leaving the water. Should there be several faults, as each was lifted out, a backward swing of the needle would occur.

Electrical cables for submarine mines should be rejected if showing anything under 1000 ohms insulation resistance, and whenever practicable a cable showing bad insulation should be returned to the depôt for repair.

For Copper Resistance.—To test the copper resistance of the core or cores of a multiple cable, a balance is obtained on the bridge *B*; the only difference in the connections being that, instead of the pole of the battery being put to earth, it is attached to the *d* terminal, to which the previous free end of the cable is also connected; see Pl. XXXVI., Fig. 2.

Each core of a multiple cable (of *n* cores) may be tested for copper resistance *separately*, or they may be connected up to give a continuous circuit of *n* times the length of the cable, and one measurement of the resistance taken, which divided by *n* will give the resistance of each core, and this result verified by testing one core separately: thus only two instead of seven separate tests for a 7-core multiple cable would suffice. The core of an electrical cable for submarine mines has a copper resistance of 12 ohms per knot.

In making this test, it is better to use the proportion *a b* (100$^{\omega}$): *a c* (10$^{\omega}$), and so obtain a resistance on *d e* of some 120 ohms, depending of course on the length of the cable under test.

For Continuity.—This test is a very simple one, and is made by connecting *a* to *b* in Pl. XXXVII., Fig 1, when, if the continuity of the core is good, a violent swing of the needle of the galvanometer *G* will result. If no deflection occur then the core will be broken; and if it is necessary to use this broken cable, what is termed the "discharge" test will have to be made to discover the position of the break or breaks. The discharge test is made as follows: put one pole of a powerful battery to earth, and charge one end of the defective cable, then immediately discharge it through the galvanometer *G*, and note extreme limit of swing of needle, repeat the operation with the other end of the cable, and also note limit of swing: repeat the operation for each end and take mean of the reflections, and then the proportion between the mean deflections for each end will denote accurately the position of break, and the cable may safely be cut at that point. Should the precise position of the fault not be by this means discovered, each piece of the cable must then be again tested for continuity, and that one in which a fault was still found to exist must be again tested by the discharge test.

PL. XXXVII

Fig. 1

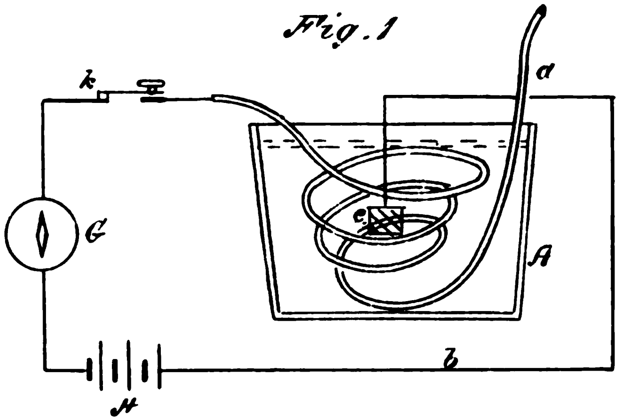


Fig. 2

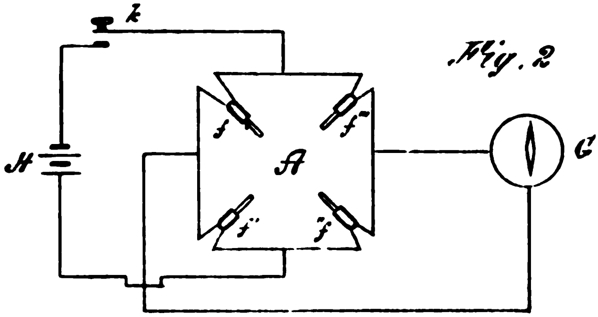
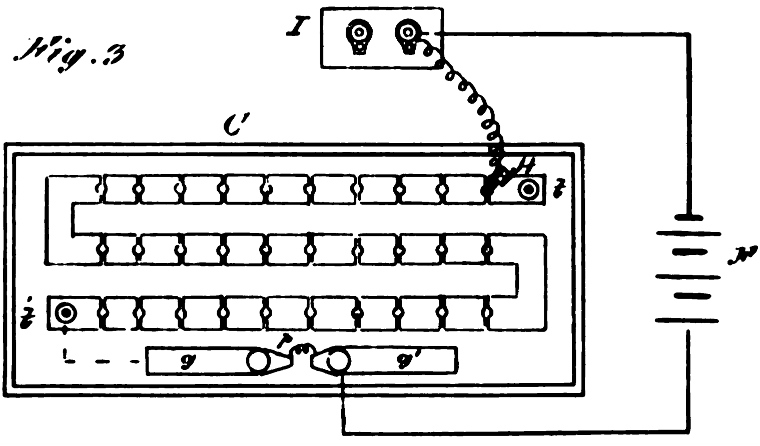


Fig. 3



& Co.

PORTSMOUTH.

It will therefore be better to test at the mine station by means of the Wheatstone bridge on the station test table the actual resistance of each fuze before passing it for use, rejecting those not showing the standard resistance. In Pl. XXXVII., Fig. 2, is shown a simple plan of testing the condition of mine fuzes, and it might be desirable to provide this arrangement at each station.

Four copper wires of the same length and gauge, or with opposite pieces of same length, are fastened to a board as shown at A, Fig. 2, having their ends turned up with connections to which to attach four fuzes f, f', f'', f'''; to the centre of each of the copper wires connecting these fuzes together, a wire of equal length is attached, and connected up to the galvanometer G of the station test table in circuit with the test battery and key k, as shown in the figure.

The four fuzes will then form part of a Wheatstone balance, and if their resistances be equal, no deflection of the needle G will be observed on pressing down the key k. When four fuzes have been found to give this result, three of them are left permanently attached as standard resistances, and the fourth pair of fuze points is marked: then to test other fuzes place them in succession on the marked pair of points, and press down the key k. Any motion of the needle either way will show something wrong, and the nature of the defect will be indicated by the direction in which the needle moves. If a deflection occurs, first connect the points of the experimental fuze with a piece of copper wire, *i.e.* short circuiting it, to show whether the deflection is due to too little resistance; secondly, remove the fuze altogether to ascertain by the deflection whether it is due to a broken bridge.

Of course where a lot of fuzes are at hand, and when it is only desired to obtain a certain number of good fuzes, the cause of a deflection to the right or left need not be traced, but only those fuzes giving a balance be taken.

For Efficiency.—The efficiency of fuzes whose electrical condition has been found perfect, can only be tested by actually exploding them through a resistance representing the resistance of the circuit they will be connected up in on actual service, and knowing the internal resistance (r), and E. M. F. (E) of each firing cell, resistance of the bridge of the fuze (f) when red hot, and resistance of the line (R), as well as the actual current needed to make the bridge red hot (c), the number (n) of firing cells that ought to explode the fuze can be readily calculated from the following formula :—

$$(1) \quad c = \frac{n\,E}{n\,r + f + R}$$

Suppose $c = 0\cdot5$ ampere.
$E = 1\cdot9$ volts.
$r = 0\cdot2$ ohm.
$f = 0\cdot77$ „
$R = 15$ „

then formula (1) becomes

$$0\cdot5 = \frac{n \times 1\cdot9}{n \times 0\cdot2 + 0\cdot77 + 15}$$

$n = 5$ cells to explode the fuze.

If with 5 cells tho requisite current is not obtained, then one or more cells must be added until the current c is reached. If with the current c the fuze is not exploded, and yet the resistance of its bridge agrees with the standard measurement, this will show that the priming is at fault, and another fuze out of the same box or lot should be tested in the same way.

Testing Disconnector Fuzes for Resistance and Efficiency.—The same process of testing for resistance of bridge would have to be carried out with the disconnector fuze as described for the mine fuze.

For efficiency, however, a circuit should be made up of a disconnector and mine fuze with resistances, representing the other parts of the mine circuit, and fire the mine fuze with a current of a strength equal to that which is capable of fuzing or deflagrating the wire bridge of the fuzes. After exploding the mine fuze test the circuit to prove whether the disconnector has acted properly in insulating or breaking the continuity of the mine circuit.

Testing Batteries for E. M. F.—The E. M. F. of a cell can be obtained by means of a tangent galvanometer. This galvanometer is provided with two scales on the dial, the upper portion being marked in degrees, and the lower in tangents. Then a standard Daniell cell (E. M. F. 1·08 volts) is connected up with a suitable resistance to deflect the needle to 1·08 on the tangent scale.

To find the E. M. F. of any other cell, connect it up to the tangent galvanometer through this resistance, and note the reading on the tangent scale. Suppose this reading to be 2, then E. M. F. of cell under test will be as 2 to 1·08, or 1·85 volts.

It might be as well to combine in the station test table a tangent galvanometer of this description.

For Internal Resistance.—To test a battery of similar cells for internal resistance, a very simple way is to divide it into two sets, connect each set up in series, and the two positive poles together, and then treat the battery as an ordinary resistance, and measure it by means of the Wheatstone bridge of the station test table in the ordinary way.

The internal resistance of a cell may be also ascertained by the following method:—

Form a circuit of the cell, galvanometer, and suitable resistance r, and note swing of galvanometer needle d; then join a second cell to the first in parallel, and by adjusting the resistance r to r' bring swing of the needle to d. Calling E. M. F. of cell E, f its internal resistance, and R the resistance of the galvanometer and leads, we have for the one cell:—

(1) $d = \dfrac{E}{f+(R+r)}$ and for the two cells in parallel

(2) $d = \dfrac{E}{\frac{1}{2}f+(R+r)+r}$. Combining (1) and (2) we get $f = 2\ r'$, or the internal resistance of the cell is equal to twice the extra resistance interposed in the circuit to bring the reading for the two cells to the same as for the one cell.

Testing Firing Batteries for Power.—For this test the 100 ohms resistance box C of the station test table is used; a diagram of the connections is shown in Pl. XXVII., Fig. 3. Unplug all the resistances between t and t'; connect a piece of iridio-platinum between the jaws g, g' representing the wire bridge of the fuze to be fired by the battery; connect the carbon of firing battery to the jaw g', and its zinc to the terminal I, and close the circuit by inserting the wandering plug H: then plug up the resistances unit by unit until the test wire p becomes red hot, after which, by means of the wandering plug H, reduce the resistance $\frac{1}{20}$th ohm at a time until the wire p is fuzed: the resistances remaining unplugged will then be a measure of the strength of the firing battery, *i.e.* it will be capable of firing a fuze, whose bridge is similar to p, through this unplugged resistance.

Testing the Directive Instruments.—Directive instruments require to be tested to prove their electro-mechanical efficiency.

The nature of these tests will depend on the system of directive instruments in use, and here it will be only necessary to detail those tests which must be carried out in connection with a circuit-closer, shutter apparatus, the intersectional arc, such as are described at pages 50, 103, and 111 respectively.

In all these instruments the various circuits must first be tested for continuity, which can be readily done by means of the ordinary detector galvanometer and battery described at page 95; then in the case of resistance or other coils these must be measured for conductivity resistance in the ordinary way by the Wheatstone bridge on the station test table.

Then test the shutter apparatus to find the minimum current that through an interposed resistance representing the mine circuit will cause the shutter to drop, *i.e.* will attract the armature against the holding-off spring; break the circuit, and prove strength of this spring to draw back armature.

Put circuit closer in circuit with the shutter apparatus with the same interposed resistance, and switch in the signalling battery to prove that its current with the 1000 ohms resistance of the circuit-closer in circuit is not strong enough to attract armature: then cause the circuit-closer to cut out its resistance coil by shaking it violently, &c., and prove power of signalling battery to cause the shutter to drop when the 1000 ohms resistance is thus cut out.

The armature of the circuit-closer electro-magnet must also be adjusted, so that the motion of the mine containing it shall not cause the circuit-closer to act prematurely. It will be sufficient to lay the circuit-closer on its side, and adjust armature to just make contact.

The intersectional arc requires to be tested only for continuity between its various contacts by means of an ordinary detector galvanometer and battery. In the same manner a similar test must be made with a series of firing keys, or a single one.

The foregoing briefly indicates the kind of tests that are necessary with directive instruments.

Testing the whole System.—This operation will have to be performed for each mine as it is planted, and for the whole system at stated intervals daily, a careful record being made of the results of these tests, the value of which for indicating at any time the electrical condition of each circuit will depend on the amount of care that has been taken in carrying out the various preliminary tests in the manner explained in this chapter.

In Pl. XXXVIII., Figs. 1, 2, and 3, are shown diagrams of three different arrangements of mine circuits, for the purpose of explaining the nature of the daily tests of a system of submarine mines.

C Z is the testing battery, one pole to earth at *x*; *P, Q, O,* the shutter commutator; *E* the shutter electro-magnet coils; *N, M,* the shutter main terminals; *W* the main cable; *w* the mine cable; *r* the resistance coil (1000$^{\omega}$) of the circuit-closer relay; *f* the fuze, put to earth at *e*.

In Fig. 2 *w'* is the circuit-closer cable: in this case the circuit-closer is put to earth at *e*.

In Fig. 3, *d, d, d,* are the disconnector fuzes.

From the preliminary tests the following details of the circuit in Fig. 1 would be known.

Resistance	from *O* to *M* suppose	20	ohms.
"	of *W* (2 knts.) "	24	"
"	" *w* (203 yds.) "	1·2	"
"	" *r* equal to	1000	"
"	" *f* + *f* " "	1·54	"
"	" earth-circuit, suppose	1	"
	Total resistance of circuit	1047·74	"

Connect up the testing battery to the galvanometer *G* of the station test table with this total resistance of 1047·74 ohms inserted in the circuit, and note deflection of needle with both the positive and negative current, and tabulate results; then the electrical condition of the mine circuit after it is laid down can be ascertained at any time by comparing the deflections then obtained, using the same testing battery and galvanometer, with the tabulated ones, and if these two readings correspond, or nearly so, the condition of the circuit may be considered as good and serviceable.

Accidents in Mine Circuits.—The damages a mine circuit is liable to are manifold, but in a carefully devised system, where due attention has been paid to the joints, the fixing of the multiple and mine

PL. XXXVIII

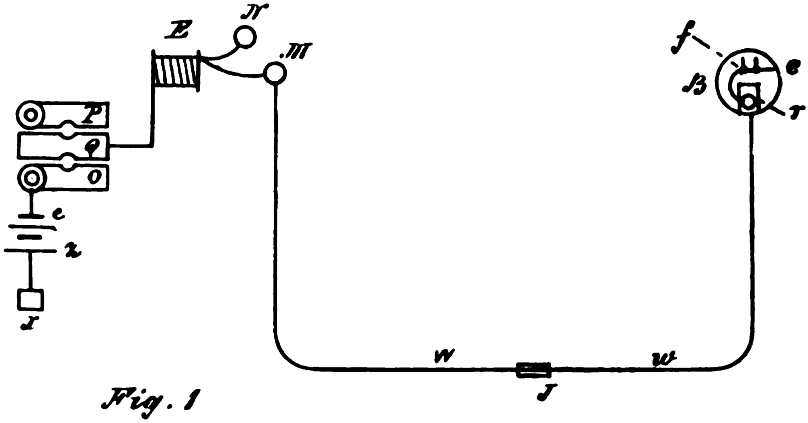


Fig. 1

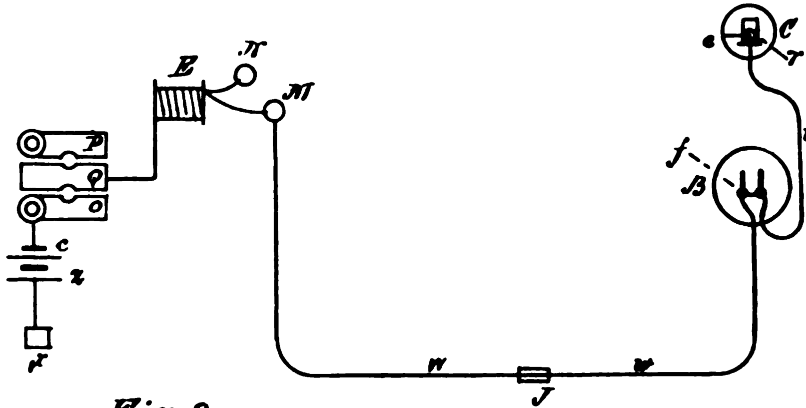


Fig. 2

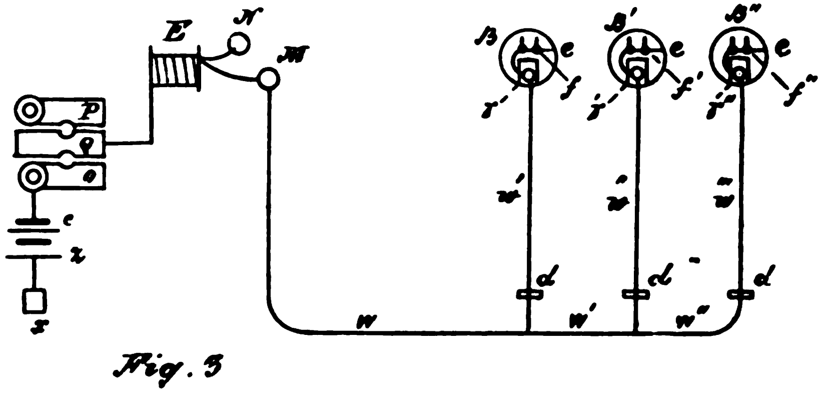


Fig. 3

cables in the junction box, the connections of the mine cable in the mine and the circuit-closer case, where the circuit-closer is of simple construction, and not too delicate, and where efficient and carefully-tested fuzes are employed, there is no reason why the efficiency of the mine circuit should be impaired by the fact of its being a submarine circuit, with the fuzes and circuit-closing apparatus not open to inspection; and provided that a mine circuit is in perfect condition when laid down it ought to remain so for any reasonable length of time, unless it should be damaged by the machinations of an enemy, or by some other extraneous cause, such as a vessel anchoring in a position to weigh a mine or multiple cable with her anchor, and thus break it, or damage its insulation, or again by a mine being sunk by the blow of a friendly vessel colliding with it.

All accidents happening to a mine circuit sufficiently serious to militate against its action can be readily discovered at the mine station, though its precise nature may not be discoverable, with the exception of the sinking of a mine, or circuit-closer case, though it is even possible to ascertain this by means of a telephonic test, as will be explained later on.

Consider first those faults which may occur from natural causes due to defective apparatus, as, for instance, the short circuiting of the high (1000^{ω}) resistance coil *r*, or the breaking of the bridge of the fuze *f*. In the event of the former accident occurring in the case of circuits 1 and 2 in Pl. XXXVIII., the effect would be to permanently reduce the total resistance of the circuit of the mine in which this happened by 1000^{ω}, and with the signalling battery in circuit, *i.e.* with the plug inserted between *P* and *Q*, the shutter of that mine would at once fall, and could not be retained in the horizontal position; and supposing the firing battery to have been in circuit at the same time the mine would have been exploded at the moment of the shutter dropping, or in other words at the instant of the short circuiting of the coil *r*. If the firing battery be not in circuit, the same effect would be produced by the mine cable *w* being cut, and put to earth, as by the short circuiting of the resistance *r*, and only by the most delicate tests would it be possible to discover which of the two had happened, but in either case the mine would be rendered useless.

In circuit No. 3 the short circuiting of either of the coils *r*, or the cutting and putting to earth of either of the mine cables w^1, w^2, w^3, would cause the shutter of the *single* instrument which operates the whole of the mines on its single-cored main cable W to permanently fall, and practically put that group of mines out of action, unless the firing battery be put in circuit to explode, and insulate the mine in which the coil r is short circuited, by firing the disconnector in connection therewith.

In the case of a broken fuze bridge, this would mean, in circuits 1 and 2, loss of continuity of the mine circuit where this happened, which would be shown on putting the testing battery in circuit by the impossibility of obtaining any reading on the galvanometer, and that mine would become ineffective. A similar accident occurring to one of the fuzes in the mines of circuit No. 3 could only be ascertained by the difference in the reading on the galvanometer then obtained, with the testing battery in circuit, as compared with the tabulated reading, as such an occurrence would only alter the *amount* of the total resistance of the whole circuit, though of course throwing that mine out of circuit; but the number of the mine thus affected could not be ascertained at the mine station with mines laid down on the branch cable system.

The severing of the *main* cable and insulation of the end by the enemy would in either of these cases be shown by the failure to obtain any reading; in the first two cases this could be in a manner proved by no reading being obtained from each mine put separately in circuit.

The cutting of a *mine* cable by the enemy and insulation of the end would affect the circuit in the same manner as in the case of a broken fuze bridge, and could be similarly discovered.

In the event of a mine or circuit-closer case being sunk by the blow of a passing vessel, no indication would be afforded of any accident having happened unless the water penetrated into the circuit-closer and short-circuited the high resistance coil, though then the actual nature of the accident would not be known. By the use of the telephonic test it would, however, be possible to ascertain that a mine had been sunk in the following manner. This test consists of a telephone at the mine station, and one in each of the circuit-closers, the latter being provided with loose shot placed on the diaphragm: any motion of the mines would then be indicated through the movement of these shot in the circuit-closer telephone by the telephone at the mine station. Suppose that of seven mines on the same circuit six of them transmitted the sound caused by the rolling of these shot in their telephones, and the seventh mine failed to transmit any such sound, it would indicate that this mine alone was absolutely at rest, or in other words had probably been sunk.

CHAPTER VII.

GENERAL PRINCIPLES OF SUBMARINE DEFENCE.

1. The two main principles of Submarine Defence—2. Consideration of the first principle—3. Consideration of the second principle—4. Considerations in planning a Submarine Defence—5. Nature of "Refuge" Channel—6. Position of the Mine-field—7. Class of Mines to be used—8. Disposition of the Mines—9. Positions of the Mine Stations—10. Mode of introducing the Electrical Cables into a Fort—11. Isolated Mine Station—12. Protection of the Mine-field—13. Special Marine Defences—14. The Method of Planting a System of Submarine Mines—15. Tables of particulars required in Planting Mines—16. Description of vessels used in laying down Mines—17. The operation of buoying the Mine and Junction-box positions—18. Laying out the Mine Electric Cables—19. Planting Mines Fired by Observation—20. Planting Electro-contact Mines—21. Description of a general sketch of the Submarine defence of the entrance to a harbour.

AN ideal harbour defence by submarine mines should permit of an arrangement whereby it would be impossible for the ships of an enemy, having for their purpose the bombardment of that harbour, to place themselves within its effective range without passing over some portion of the mine field, but owing to the increased effective range of modern ship artillery, and the difficulties attendant on the mooring of mines to seaward of a harbour, this is not feasible in practice; therefore the object of a mine defence is now-a-days limited to the prevention of the entrance of a harbour being *rushed* by one or more of the hostile vessels, which, were there no mine defence, would be a possible proceeding with the present heavily armoured high speed ironclad, even in the face of the powerful guns that are now to be found in the land works of all first-class harbours.

The Two Main Principles of Submarine Defence.—The two main principles on which the defence of harbours by submarine mines is based are as follows:

1. The arrangement of the mines in positions such that it would not be possible for a hostile vessel attempting to force a passage into a harbour defended by such means to pass more than one line of them

without coming within the destructive radius of some one or other of the mines of the remaining lines.

2. The complete protection of the mine field by the guns of the defence, either those of the principal landworks, or of specially constructed batteries, or of guard ships.

Consideration of the First Principle.—In regard to the first principle, the difficulty of fulfilling it lies in the fact that the destructive radius of a submarine mine is considerably less than the distance that must be maintained between any two of them to prevent injury to the mine case, or electrical apparatus contained therein by the concussion of a neighbouring mine explosion.

The extreme destructive horizontal range of different sized mines charged with gun-cotton as computed by General Abbot is as follows:

Charge.	R.
100 lbs.	14·7 feet.
200 „	20·5 „
500 „	31·7 „

The necessary interval for safety that must be maintained between two mines is at least 8 R., so that the 100-lb. mines must be planted at a distance apart equal to 8 × 14·7 or 115·2 feet: for the 200-lb. mines 8 × 20·5, or 164 feet: and for the 500-lb. mines 8 × 31·7, or 253·6 feet. The safety interval less twice the destructive radius will then represent the actual undefended space, so far as fatal injury to a first-class ironclad is concerned, representing 85·8 feet, 123 feet, and 190·2 feet respectively for two 100-lb., 200-lb. or 500-lb. (gun-cotton) mines.

The radius here referred to is that at which the strongest ironclad afloat would receive a fatal injury, but such a vessel moving ahead under steam might sustain serious damage to her machinery, &c., at a distance equal to possibly twice this destructive radius.

The diagram in Pl. XXXIX., Figs. 1, 2, and 3, represents the destructive, dangerous, and safety areas of a 500-lb., 200-lb., and 100-lb. mine charged with gun-cotton: a ship within the inner circle *a* at the moment of the mine *m* being fired would receive a fatal injury, and within the circle *b* but without *a* would sustain more or less serious damage according to its distance from *a*: a mine planted within the circle *c* would be liable to be either rendered useless by its circuit closer being damaged, or by being sunk, or prematurely exploded, on the explosion of the mine *m*; and a similar result would happen to the mine *m* if the former be fired instead of the latter.

Consideration of the Second Principle.—The second principle is a most important and necessary one, for a submarine mine defence left wholly unprotected by guns, or unguarded by armed high-speed boats, would be readily disabled or destroyed by an enemy having the needful time and the necessary material; and not only do the mines require to be efficiently protected, but also the mine and observation stations must be securely defended from assaults by landing parties from the attacking fleet.

In certain exceptional cases where a place is deemed to be sufficiently defended by a number of *self-acting* mines for the sole purpose of denying its use to the enemy, either for effecting a landing, or for any other object, it would possibly not be necessary in such a case to provide the mine field with a gun protection, though even here a gun defence would very materially increase the utility of the mines by increasing the difficulties of clearing the harbour by the enemy in the event of their being obliged, for some reason or other, to make use of this place.

In fact it ought to be considered as an axiom of harbour defence that the submarine mine portion of it must be, and is worth being, protected by guns and guard boats against countermining, and other operations that the enemy may attempt with a view to render the mine field innocuous; inasmuch as the gun defence of a harbour needs the assistance of the submarine mine to render it effective, so does the mine need protecting by the gun to secure its greatest efficiency.

It must be remembered that the cutting of a multiple cable means the rendering of all the mines in circuit therewith inactive, representing in the usual method of connecting up the groups of mines as shown in Pl. XLI., Fig. 1, the opening of a safe passage to the enemy of some 200 yards to 100 yards in width according as seven or five 500-lb. mines constitute a group: however, this may be to some extent remedied by arranging each set of mines in circuit with a multiple cable in lines, as in Fig. 2, instead of in groups, when the cutting of a multiple cable would only mean the loss of the mines in *one* line; but even here such a disaster would very seriously weaken the effectiveness

PL. XXXIX

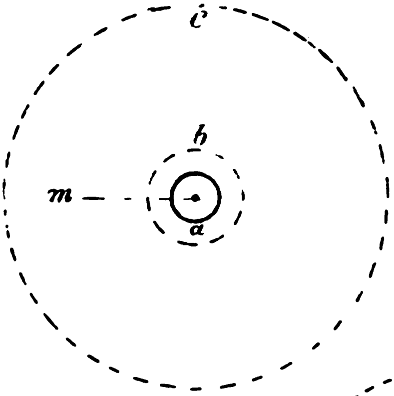


Fig. 1

Fig. 3

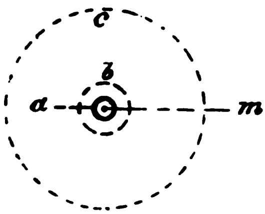
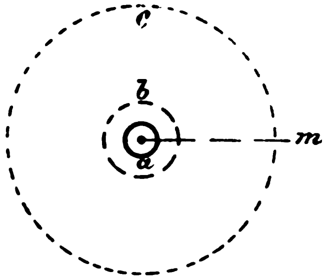


Fig. 2



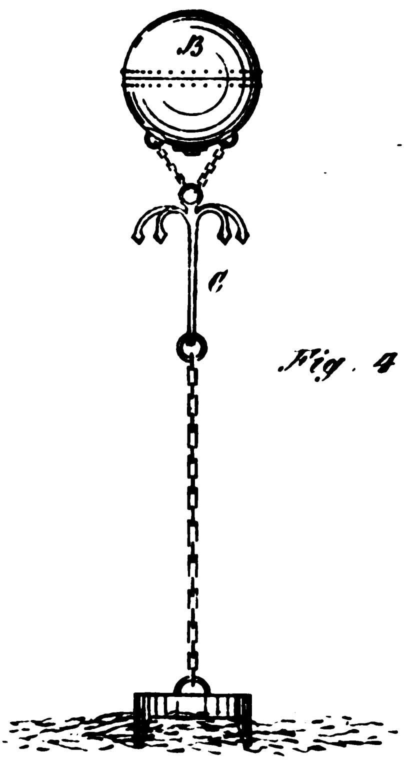


Fig. 4

of the mine defence. Similarly in the case of a number of electro-contact mines in circuit with a *single* cored main cable, the destruction of the latter would involve the loss of the former. If no disturbing element be present, it is by no means a very difficult work to creep for, pick up, and cut an electric cable; and as a successful operation would result so disastrously to the defence, it is imperative that a disturbing element of considerable magnitude should be at hand to interrupt such work, in the shape of guard boats, guns covering the whole mine field, electric lights, &c.

Considerations in Planning a Submarine Defence.—The preparation of a scheme of submarine defence for the sea board of any country entails a very great number of considerations; first of all it would be necessary to decide as to the places, harbours, open roadsteads, rivers, &c., to be so protected: and secondly, which of them are to be treated as "harbours of refuge," that is open at all times to the passage in and out of friendly ships, but closed to the enemy, and which of them are to be entirely closed both to friend and to foe.

These points being settled, then there has to be considered the details of the mine defence for each particular place, the nature and quantity of which varies according (1) to its local features; (2) to the importance of the position; (3) to the views of those officials responsible for this work; (4) and to what is even a more important and varying factor—the amount of money provided therefore; and as these factors are regulated by no fixed law, it is impossible to formulate any definite general scheme of submarine defence, but all that can be attempted here is to suggest various points of consideration, and to explain how the operation of actually planting the different classes of mines may be carried out.

First, take the case of an important harbour such as a naval port possessing an arsenal and dockyard, which would, of course, have to be treated as a "harbour of refuge."

In preparing a plan of defence of any place by submarine mines, it is, first of all, necessary to provide a chart on a scale of at least six inches to the mile, and on this must be marked the position of each existing fort or battery, as well as of those it is intended to construct for the special work of protecting the mines, the firing, and converging stations, also the lines of low-water soundings, and all the available information as to direction and rate of currents and tides, nature of bottom, direction of prevailing winds, rise and fall of tide, &c.

Then, with this carefully prepared chart at hand, the following points have to be considered and settled:—

1. Nature of "refuge" channel.
2. Position of the mine-field.
3. Class of mines to be used.
4. Dispostion of the mines.
5. Position of the shore-mine station.
6. Protection of the mine-field.
7. Special defences.

These questions involve a multitude of considerations, and become so complex, owing to their dependence on the local features of any particular place that it is only possible to briefly touch on them in a general way.

Nature of "refuge" Channel.—A "refuge" channel is the passage which, by the use of the controlled submarine mine, can be opened to friend, but closed to foe, and this passage may constitute the whole width of a harbour entrance or entrances, or only a portion thereof.

Suppose the place under consideration has but one entrance, say 4000 yards in width at the outer boundary of the proposed mine field, the question then is whether the whole of this space shall be treated as a "refuge" *entrance*, that is planted with controlled mines, or shall only a portion of it, forming a winding refuge *channel* 2000 yards in width for instance, be thus defended, and in the remaining portion be planted *self-acting* mines only.

In the case of a harbour possessing a "refuge" *channel* of this description, it would be necessary to provide a staff of reliable official pilots to conduct friendly ships in and out, and every precaution would have to be taken to prevent the enemy from obtaining a knowledge of the position and direction of this channel; this work could be effected in war time with comparative ease in ordinary weather, and under ordinary circumstances; but circumstances might arise when the fact of the captain of a friendly ship being ignorant of the leading marks of this channel might prove disastrous and even fatal to his ship; as, for instance, when seeking refuge in the harbour from stress of weather, or from an enemy's war ship close at his heels.

It may, therefore, be laid down as a rule that any important place intended as a *general* "harbour of refuge" should be planted in its entirety with *controlled* mines, the use of self-acting mines being restricted to such places it is desired to close altogether, or for the defence of certain portions of those places that military exigencies require to be used as *naval* "harbours of refuge," that is to say, for the use of war ships only, the commanders of whom would be acquainted with the proper courses to steer in seeking refuge therein.

It may be that the place under consideration has two entrances; the question then arises as to whether both shall be defended as "refuge" entrances, or whether one, and if so, which of them shall be closed entirely by self-acting mines, booms, &c.

Position of the Mine Field.—Suppose, then that a decision has been arrived at as to the kind of "refuge" channel to be provided, the next point to be considered is the position and number of mine fields: the outer field, if more than one, should be placed right at the harbour entrance, choosing the narrowest width from shore to shore for the outermost row of mines. The number of fields will depend on the size, importance, and local features of a harbour. For example, take the case of Plymouth harbour; here there are two entrances to the anchorage formed by the breakwater, and also to the inner port formed by an island, and it would be therefore necessary to form a mine field in each of the outer and inner entrances.

Class of Mines to be used.—Now comes the consideration of the class of mine to be adopted; where the depth of water is sufficient to permit of the passage of the larger class of war ships, the 500-lb. gun-cotton mine should be used either as simple electro-contact mines, or in combination with a separate circuit closer case, if the depth of water be too great for the former system; these would have to be arranged for observation as well as contact firing.

In channels and reaches, and also on the flanks of the more powerful mines, where the depth of water permits of the passage of small vessels only, the 100-lb. electro-contact mine should be used, and arranged on the branch system from a single-cored main cable; while in still shallower places open only to the passage of torpedo and other comparatively light-draught vessels, the 50-lb. electro-contact mines, arranged on the same system, would suffice; these might support, or be supported, by booms or such like passive obstruction to prevent the main mine field being circumvented by the torpedo boats of the enemy. In these latter positions self-acting mines might, of course, be used for the sake of cheapness, but it is better to rely altogether on *controlled* mines for the defence of an important harbour, the entrance of which should be entirely open to the manœuvres of the *defending* torpedo and guard boats, or otherwise on a dark night accidents might happen to the latter through their getting by mistake into the field of self-acting mines.

In places where there is experienced an excessive rise and fall of tide, special means must be taken to ensure one or more of the rows of mines being in effective position at all times, no matter what the state of the tide may be; at the present time no satisfactory self-acting arrangement exists for maintaining the mines at a fixed depth below the surface of the water whatever be the amount of the rise and fall of tide, though the great importance attaching to this question should offer a sufficient inducement to torpedo scientists and inventors to devise a solution of this surely not unsolvable problem.

The plan usually adopted in these circumstances is to moor the outer row of mines, so that they shall be at the proper depth below the surface at low water, the middle row for mean, and the inner row for high water.

By such an arrangement the mines of the middle and inner rows will be exposed at dead low water, and though still active as contact mines, they will be more or less out of position for observation firing; at the top of high water the mines of both the outer and middle rows will be inactive as contact mines, being then too far below the surface, though in proper position for observation firing.

In Pl. XL., Figs. 1, 2, and 3 show the arrangement of three rows of mines in a place where the rise and fall of tide is supposed to be 40 feet, and the depth at low water 30 feet. Fig. 1 represents the outer row of mines, 10 feet below the surface at low water, 30 feet, and 50 feet at half or mean, and high tide respectively; S, S^1, S^2 represent the section of a ship 50 feet beam, and 25 feet draught of water, in position at each state of the tide.

Fig. 2 represents the middle row of mines 15 feet below the surface at half tide, and 35 feet at high water: m^1 shows position of mines at low water.

PL. XL

Fig. 1

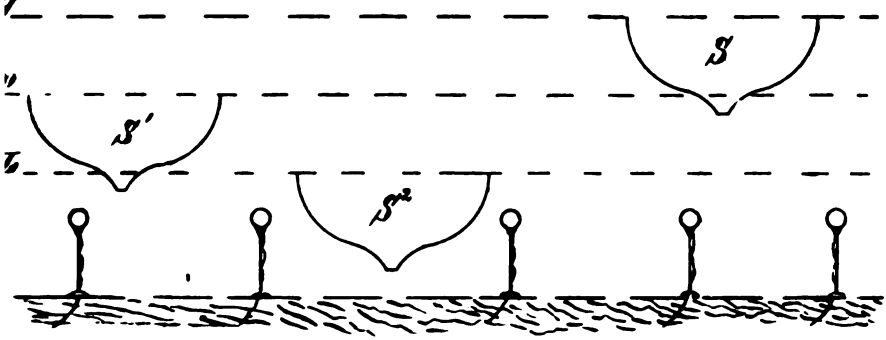


Fig. 2

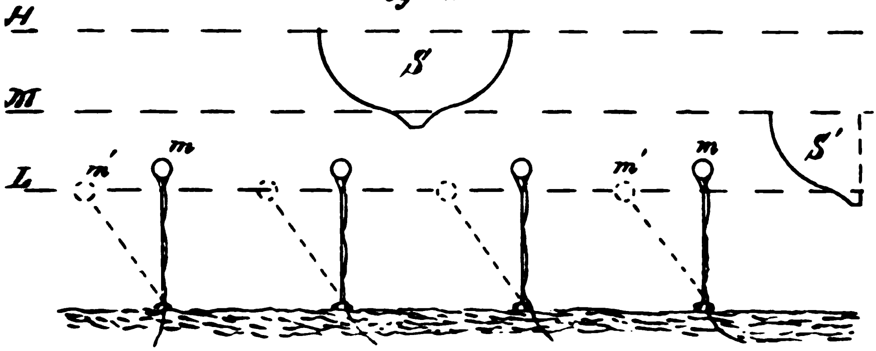


Fig. 3

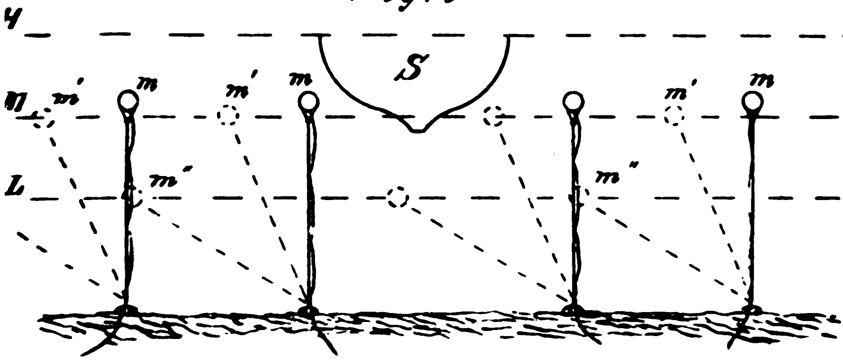


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Fig. 3 shows the inner row of mines, 15 feet from the surface at high water; m^1, m'', represent the mines at half and low water respectively.

One of the best of the automatic mooring arrangements for mines placed in tidal harbours is described in Chapter III., page 72, but good as it undoubtedly is, it is not perfect, owing to its working parts being submerged and unprotected, and therefore liable to be clogged after being in use for any long period of time.

It is surely, in these days of the application of electricity to almost every branch of industry, not beyond the powers of any clever practical electrician who may consider it worth his while to study this problem to devise a simple method by which he shall place in the hands of the submarine miner a means whereby he can at any time draw down or float up a row of mines from the shore station, so as to ensure their being always completely submerged, no matter what may be the fall and rise of tide in the position in which they may be planted.

Disposition of the Mines.—The disposition of the mines, *i.e.* their arrangement in the field, is usually carried out on the plan shown in Pl. XLI., Fig. 1.

A set of five or seven mines on a multiple cable may be, of course, grouped in a variety of ways, as, for instance, in a circle around its junction-box, or in the form of a triangle, or in echelon, but the three-row formation is indisputably the best for providing an adequate protection for the greatest area with the smallest number of mines, as well as for simplifying the process of planting them, and their arrangement for observation firing.

Pl. XLI. illustrates four methods of connecting up three groups of mines; Fig. 1 represents the arrangement usually adopted, and in so far as the work of laying down the mines is concerned it is a simple one, but it possesses two serious defects, viz. that it complicates the connections at the mine station, and that the cutting of one multiple cable puts out of action a certain number of mines in *each* row, and thus opens a safe passage to the enemy through the mine field, and the latter disadvantage would be fatal were it possible for the enemy on cutting a cable to discover the position of the channel thus opened to their ships.

The complication referred to arises from the fact that each row of mines is composed of some in connection with each multiple cable, and as a separate shutter apparatus, and a separate telescopic firing arc has to be provided at the mine station for each row of mines, a certain number of cores from each of the multiple cables must be connected to these instruments.

By utilising a separate multiple cable for each row of mines, as shown in Pl. XLI., Figs. 2, 3, and 4, the defects belonging to the other method are obviated. Figs. 2, 3, and 4 illustrate three arrangements of connection where each row has its own multiple cable: if it be considered absolutely necessary to plant the junction-boxes in the rear of the mine field, then one or other of the methods of leading the cables from the mines to their junction boxes, shown in Figs. 2 and 3, must be adopted; but to avoid the complication thus entailed in laying the mines down, and as there is no practicable objection to the junction box of each row of mines being planted immediately in its rear, the method represented in Fig. 4 could with advantage be employed.

In a system of electro-contact mines on the branch system from a single-core main cable, it is better to enclose the disconnectors in, and bring all the *mine* cables to one junction-box, instead of adopting the plan represented in Pl. XV., Fig. 1, as the former permits of the connections of the main and mine cables and the disconnectors being examined at any time without much trouble, while the work of laying down a group of these mines is thereby much simplified.

The number of electro-contact mines attached to a junction-box depends on the capacity of the latter for carrying the disconnectors: not more than five mines should be used on a single-core main cable.

The power of defence of a row of five mines might be immensely increased by connecting up to each of the five cables branching from a junction-box three or more mines (instead of one) on continuous circuit, and the mines of each set arranged to be fired together; each set could be disposed in a circle, and the mines planted comparatively close together, as the set of mines being exploded as one, the question of sympathetic explosions would not apply to them; this arrangement has, however, a defect, in that each mine of a set cannot be tested separately, while of course though not requiring additional junction-boxes and main cables, yet it would be an expensive system, and further would add to the difficulties and troubles already attendant on

PL.XLI

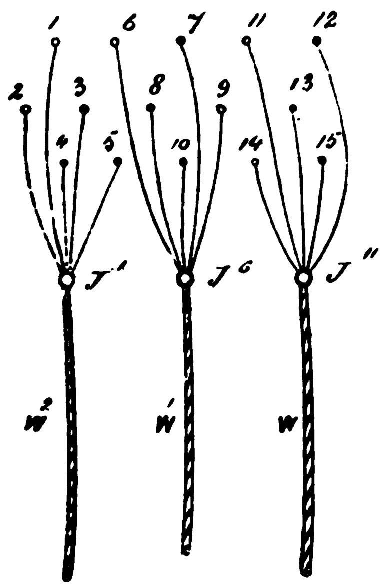


Fig. 1

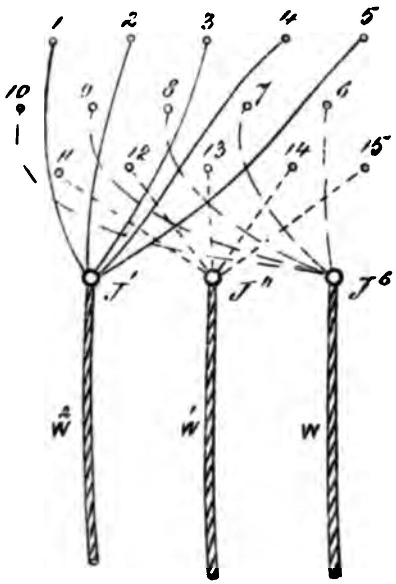


Fig. 2

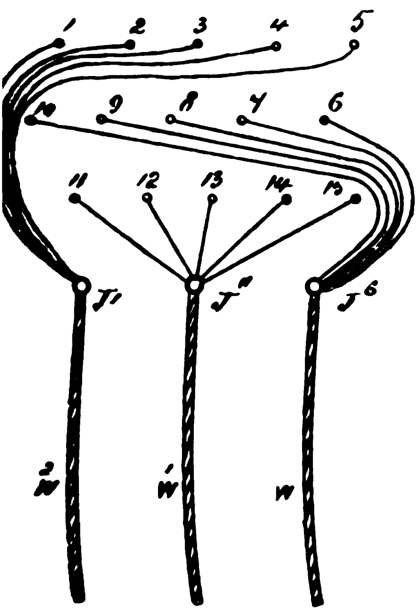


Fig 3

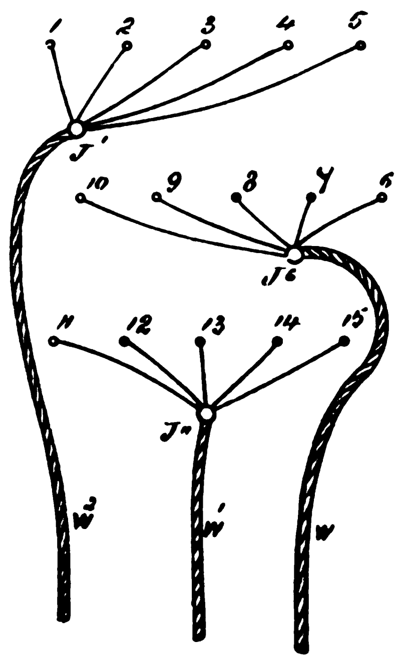


Fig. 4

planting a system of mines. For observation firing each set would be treated as *one* mine.

Positions of the Mine Stations.—The position of the principal mine station, that is the one to which all the multiple and other main cables are brought, and in which all the directive (shutter apparatus and telescopic firing arcs) and testing instruments are situated, would be in the fort, most suitably placed for the proper control and observation of the mines. The position of the station on which the rows of mines converge, where the telescopic converging arcs are situated, would be in the fort at that point. In the absence of a fort at the positions most suitable for the main, or as it is usually termed, "firing" and the "converging" stations, special works must be erected for this purpose, provided with an adequate means of self-defence against any ordinary attempt of the enemy to capture them, for the possession of a main-mine station by the enemy would be fraught with the most disastrous consequences to the defence; the capture of a converging station would not of course entail such serious consequences, as the firing of the mines by contact or "at will" would not be interfered with; but every precaution should be taken to conceal the position of such a station when it is not situated in a fort, but in a special work; it might also be mined, so that it could be effectually destroyed in the event of its falling into the hands of the enemy, and thus prevent his gaining any useful information as to the position of the mine field.

Mode of introducing the Electrical Cables into a Fort.—The introduction of the main electrical cables into the fort in which is situated the firing station is an important matter, for not only must they be protected from injury by the enemy, but also from the friction and rubbing necessarily caused by the wash of the sea.

The plan of one way of carrying out this work is shown in Pl. XLII., Fig. 1, and a section of the same in Fig. 2, where T is the testing room into which all the cables must be brought; S a store room adjoining; a shaft a, 2 ft. by 4½ ft., cut through the outer masonry of the fort provides access to the gallery b; the cut, or gallery, should be of sufficient height to permit a man to pass freely along in order to examine the cables, and 4½ ft. broad; this cut would be dry at low water, and filled with water at high tide. The shaft a is provided with a ladder; c is an iron-plated hood carried down to the level of the bottom of the sea; f is a wrought-iron diaphragm or shield through which the cables are carried, which need not be water-tight, and is only intended to prevent the wash of the sea rushing violently into the passage *b*, finding its way into the testing room *T*. A man-hole *d* gives access to the gallery at low water, and also permits the sea rushing in through the hood and checked by the diaphragm to escape without bursting in the latter.

The electrical multiple cables are carried in on a system of gun metal frames, placed at intervals along the hood and gallery: they are provided with four compartments, each holding ten cables laid in separate grooves.

Thus forty cables are carried into the testing room, representing either 40 sets of 7 or 5 mines, or 280, or 200 single cores, according to the size of the multiple cable used in the system of defence.

The width of the frame is only 2½ feet, thus leaving a space of 2 ft. for the examination of the cables.

The floor of the test room should not be less than 3 feet above level of high water at spring tide, and the outside of the hood not less than 10 feet below level of low water at spring tide.

Identity of each cable must be carefully preserved.

Isolated Mine Station.—In the event of its being necessary to place a mine station where no permanent fortification exists, it should be solidly built with a ditch all round completely flanked by machine gun and rifle fire, covered by earth blindages, and as effectually concealed as is consistent with its use as an observing station. The object being to ensure its safety against a sudden attack.

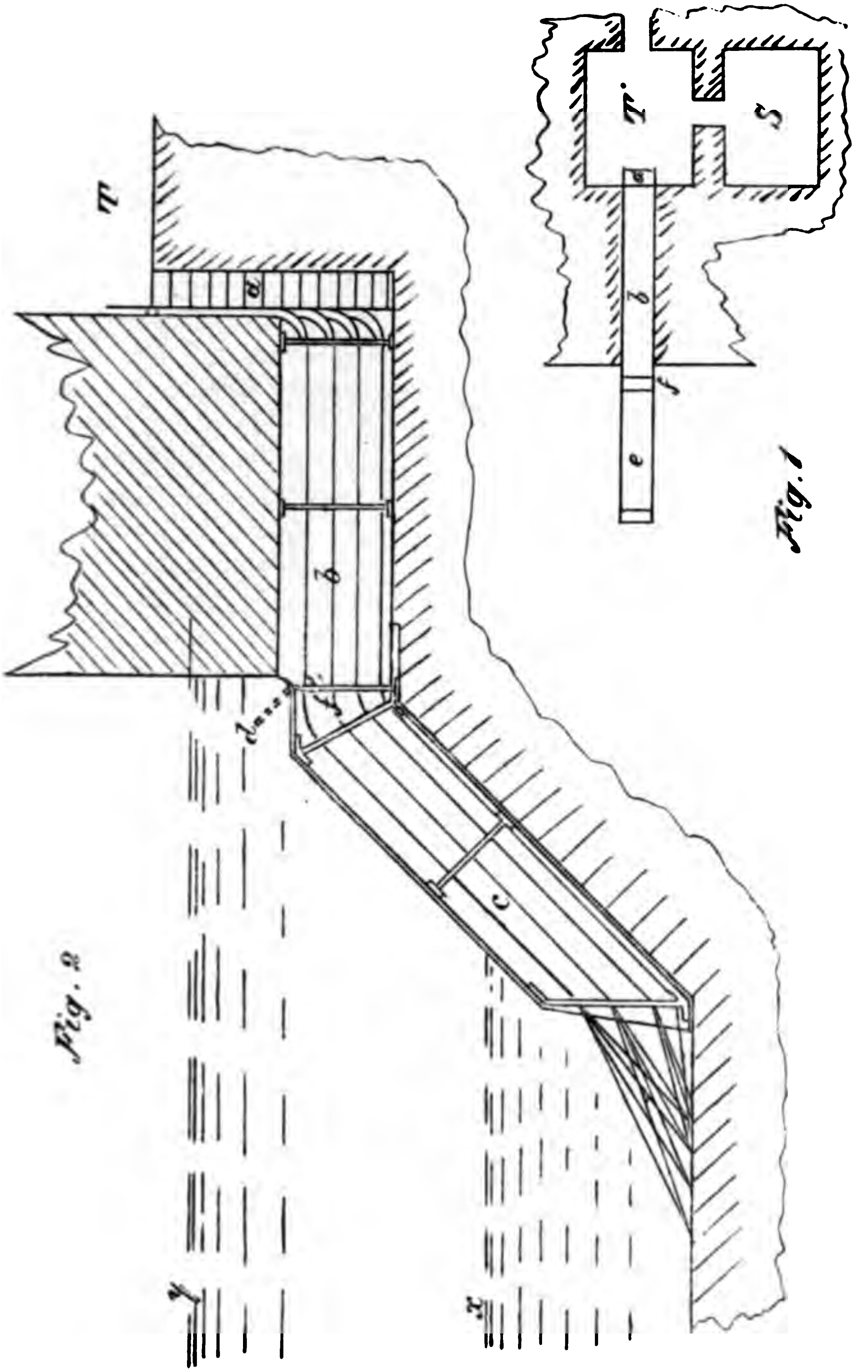
At Pl. XLIII. is shown one form of such a work, where Fig. 1 is an internal elevation, and section through *X*, *Y*, in the plan Fig. 2.

A is the testing table and shutter apparatus; *t*, *t*, *t*, observing arcs; *B* the firing battery; *S* the barrack room for the operators and guard; *c*, the cooking stove; *a*, the sink; *f*, the fire place; and *d*, the opening for the entrance of the multiple cables into the testing-room.

Protection of the Mine Field.—The mine field requires to be provided with a protection sufficient to ensure its immunity from destruction or disablement by the enemy, and as operations for the planting of counter mines, for creeping for cables, or for sweeping for mines, could only be conducted by means of steam launches, torpedo or rowing boats, the nature of the protection would only need to the most suitable to frustrate an attack of this nature.

CABLE CUT. TESTING ROOM.

PL.XLII



L. XLIII

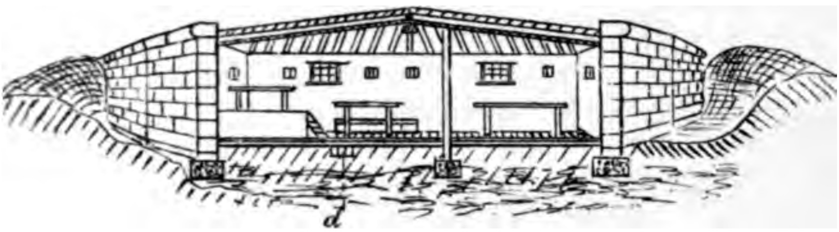


Fig. 1

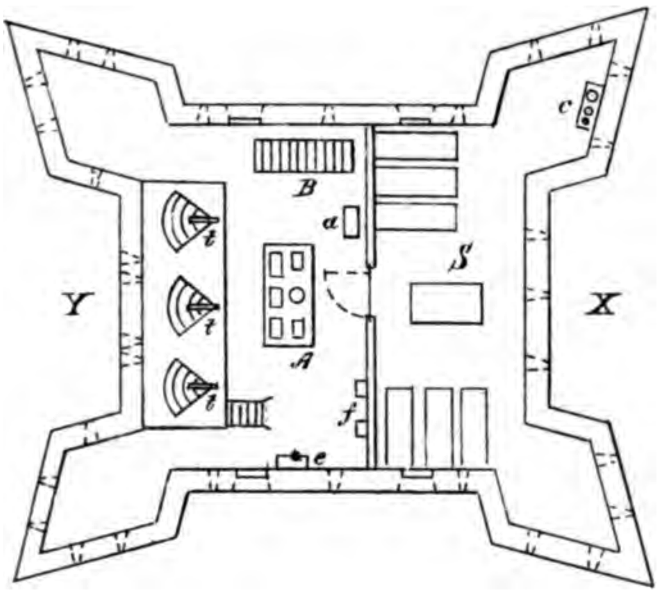


Fig. 2

Quick-firing and machine guns so situated on shore as to bring every point of the mine field under cover of their fire as the fixed defence, and torpedo boats, or steam launches, armed with this class of gun, and provided with the electric light as the offensive part of the protection, should suffice to guarantee a submarine mine defence against depredations by the enemy.

Chain cables laid down alongside the main mine cables and outside the mine field would act as an effective preventive to the picking up and cutting of the latter by the ordinary process of creeping.

The planting of dummy mines provided with an inverted grapnel, as shown in Pl. XXXIX., Fig. 4, would enhance the difficulties attendant on the operation of sweeping for the real mines.

Both these methods of obstruction would render the task of clearing away a mine defence one of considerable trouble and difficulty even in the absence of a gun and guard boat protection for the mine field.

For the purpose of ascertaining the approach of hostile boats, buoys provided with a self-acting flare light and connected together by wires in such manner that a strain coming suddenly on a wire attached to any two of these buoys, as would be caused on a boat meeting it, would instantly ignite their flare lights; a number of these buoys might be laid down every evening in advance of the mine field, at a known range from the gun defence, so that a heavy fire might be poured on the attacking boat or boats whose position would be exposed by these flare lights, as well as by the aid of the beams of electric lights, which could also be directed to this point.

It would be necessary to pick up these buoys in the early morning, and in actual practice this detector arrangement might be found, as crudely put forth here, rather troublesome to manipulate, but it has the elements of utility in a degree sufficient to warrant it, or a modified form of it, being tried.

Special Marine Defences.—In the category of special marine defences are included the passive ones, such as booms and chains, and the aggressive ones, such as locomotive uncontrolled and controlled torpedoes.

In any harbour or river not intended to be used as a harbour of refuge, passive obstruction may be employed to any extent in conjunction with self-acting mines, so as to render the work of clearing the defences away so laborious and costly as to practically prevent an enemy from making use of that place.

The Method of Planting a System of Submarine Mines.—Having now considered some of the more important questions relating to defence by submarine mines, the next operation to be discussed is that of the actual work of planting the mines and junction boxes, and the laying out of the main and mine cables.

In Pl. XLIV. a portion of the chart of the place to be defended as a "harbour of refuge" is shown with the positions of the mines, junction boxes, and of the converging and main or firing stations represented thereon; while in Pl. XLV. the process of planting the system is depicted.

In Pl. XLIV. the buoyant mines (500 lbs.), with separate circuit closer case, are represented by the character ⊙, and each is accorded a number 1, 2 . . . 15; the electro-contact mines by the character O, and marked $e^1, e^2, \ldots e^{12}$; and the junction boxes by the character ▽, marked J with lowest number of the mine of the group, each belongs to, for the former class of mine, as J^1, J^6, J^{11}; while for the junction boxes of the latter kind the marks are d^1, d^5, d^9. A is the main or firing mine station, and B the converging station; T^o, T^m, T^i, represent flags erected over the centre of the converging telescopes of the outer, middle, and inner row of mines respectively; a and b, d and e, f and g, are the flags erected on the alignments of the three rows of mines Nos. 1 to 15; p is a flagstaff set up to give the direction to be steered in paying out the main cable belonging to the junction box J^{11}. The angles subtended at each mine of the inner row by the base A T^i are taken off the chart and entered in Tables VI. and VII., which follow. At Pl. XLIV., Fig. 2, a section of the position of No. 1 mine is shown, where M is the 500-lb. mine, and C its separate circuit closer case; the rise and fall of spring tide in this place is supposed to be 12 feet; the vertical destructive range of a 500-lb. gun-cotton mine is 37 feet; the circuit closer case C will be 20 feet below the surface at high-water spring, and submerged 8 feet at low-water spring.

Tables of particulars required in planting Mines.— The following tables contain all the particulars necessary for planting a system of defence including different classes of mines :—

PL. XLIV

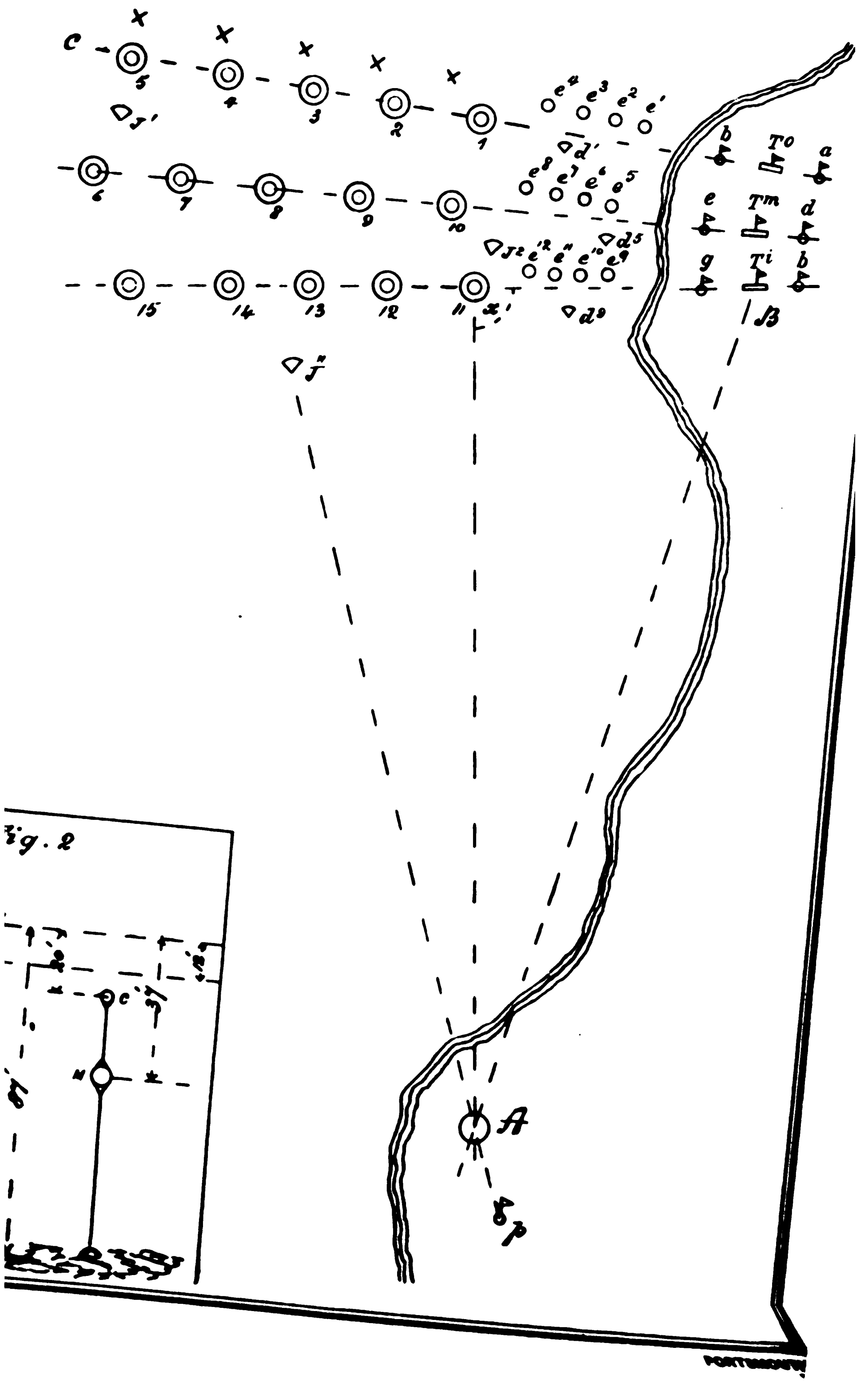


TABLE VI.—COMBINATION GROUND MINE.

No. of Mine.	Size.	Which Row.	Depth at L. W. Springs.	Rise of Tide at Springs.	Distance of top of C. C. case from		Length of				Angle for fixing Position of Mine.	Remarks.
					Bottom at L. W. Springs.	Surface at H.W. Springs.	Mine Electric Cable.	C. C. Mooring Rope.	C. C. Electric Cable.	Tripping Chain.		
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	
					a.		b.	c.	d.	e.		

TABLE VII.—COMBINATION BUOYANT MINE.

No. of Mine.	Size.	Which Row.	Depth at L. W. Springs.	Rise of Tide at Springs.	Distance of top of Mine from		Distance of top of C. C. from		Length of					Angle for fixing Position of Mine.	Remarks.
					Surface at L. W. Springs.	Bottom.	Surface at H. W. Springs.	Bottom at L. W. Springs.	Mine Electric Cable.	C. C. Mooring Rope.	C. C. Electric Cable.	Mine Mooring Chain.	Tripping Chain.		
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	
						a.		b.	c.	d.	e.	f.	g.		

TABLE VIII.—ELECTRO-CONTACT MINE.

No. of Mine.	Depth at L. W. Springs.	Rise of Tide at Springs.	Distance of top of Mine from		Length of		Remarks.
			Bottom at L. W. Springs.	Surface at H. W. Springs.	Mine Cable.	Mooring Rope.	
1.	2.	3.	4.	5.	6.	7.	
			a.		b.	c.	

TABLE IX.—MISCELLANEOUS.

Main Cables.	Junction Boxes.						Alignment Marks.			Remarks.
Size.	Length.	Letter.	Angles for Position.		Depth at L. W. Neaps.	Length of Buoy Mooring Rope.	Row.	Angles for Position.		
			R.	L.				R.	L.	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
							Outer.			
							Middle.			
							Inner.			

The particulars for filling in columns 6 in Table VI., 7 and 9 in Table VII., and 4 in Table VIII., are obtained from the instructions supplied with the submarine mine defence chart of the place. To fill in columns 8 in Table VI., 10 in Table VII., and 6 in Table VIII., measure on the chart the distance between the junction-box and the mine, and add one-third more to give sufficient slack for weighing the junction-box, and for the sweep of the current on, and sag of, the cable in paying it out. Four feet should usually be allowed for the hitches in cutting the length of the wire rope connecting the circuit closer case to the mine.

To fill in column 2 in Table IX., measure on the chart the distance between the mine station *A*, Pl. XLIV., and the junction-box, and allow one-quarter more for slack.

Description of vessels used in laying down Mines.—For the purpose of laying down a system of mines, it is necessary to employ certain vessels, such as lighters for carrying the mines, a steam tug to tow them, twin screw steam boats specially built for the work, or ordinary ship steam launches, for placing each mine in position.

These lighters should be capable of holding fourteen 500-lb. combination mines complete with their connections, and they should be fitted with two derricks amidships, one placed forward, and the other abaft; each derrick must be capable of lifting 3 tons.

For a 5-cored multiple cable, that is where each set consists of 5 mines, the lighter should have a capacity for either 2 or 3 sets, that is for 10 or 15 mines complete, and the latter size would be preferable in saving time.

The steam tug would be required to tow these lighters into position, and also for laying out the *main* electric cables as well as for planting the electro-contact mines.

The twin screw steam boats are used to carry one mine at a time from the lighter and plant it.

They should be fitted with a derrick in the bow capable of lifting 3 tons, an ordinary crab secured to the deck for working the tackle of the derrick, a roller in the stern, and one in the stem, for fair leads.

A ship's ordinary steam launch could be used for the above purpose in a land-locked harbour or in smooth water, but is not suitable for placing mines in position in rough water.

Smaller steamboats may be found useful for work in connection with making junctions between the cables.

Rowing boats would be required for the purpose of placing the buoys, laying out lines, and such like light work.

The Operation of Buoying the Mine and Junction-box Positions.—The operation of planting a system of mines consists of first fixing the position of each mine and junction-box, by a buoy marked with the number of mine, or letter of the junction-box, and then the planting of the mines and the junction-boxes in the places of these buoys.

The position of each is determined by means of the alignment of the poles *a b*, at the converging station *B* in Pl. XLIV. or XLV., and by the angle subtended by the base *A B*, which would be given in the Tables.

When each buoy is dropped, the soundings should be taken as well as the state of the tide, so as to verify the soundings given on the chart.

Laying out the Main Electric Cables.—The main (multiple or single cored) electrical cables are laid by the steam tug, a boat sufficiently roomy having been previously anchored at the buoy marking the position of the junction-box with it on board: the shore end of the cable is landed at the main station A, and the tug proceeds slowly in the direction of the junction-box boat paying out the cable as she goes, and on arriving there passes the end into this boat: this end of the cable is then connected up to the junction-box, and the latter is lowered into the water and buoyed.

If no boat be placed in position at the junction-box buoy, then on arriving close to this buoy the end of the cable would be buoyed and slipped.

The electric cable connecting the two stations *A* and *B* if separated by water is laid in the same way.

Great care must be taken to avoid bringing any undue strain on the cable in paying it out.

The end of each core of a multiple cable should be marked with the number of the mine it is to be connected up to, and corresponding similar marks at the station end, the continuity of each core having been previously tested.

A multiple cable, owing to its great weight, must always be payed off a drum: a front and end elevation of a drum for carrying ½ knot of 7-cored multiple cable, or 1 knot of single cored cable is shown in Pl. XLVI.: each drum is provided with a brake, and mounted on a strong wooden platform.

It is very necessary to have some telegraphic communication between those engaged in planting the mines and those in the main station, and it has been usual to retain one core of the 7-cored multiple cable for this purpose, but it would seem to be a better plan to provide a boat with its own cable, which it would pay out from a drum, and the necessary instruments for the express purpose of establishing telegraphic communication between the mines and the main station.

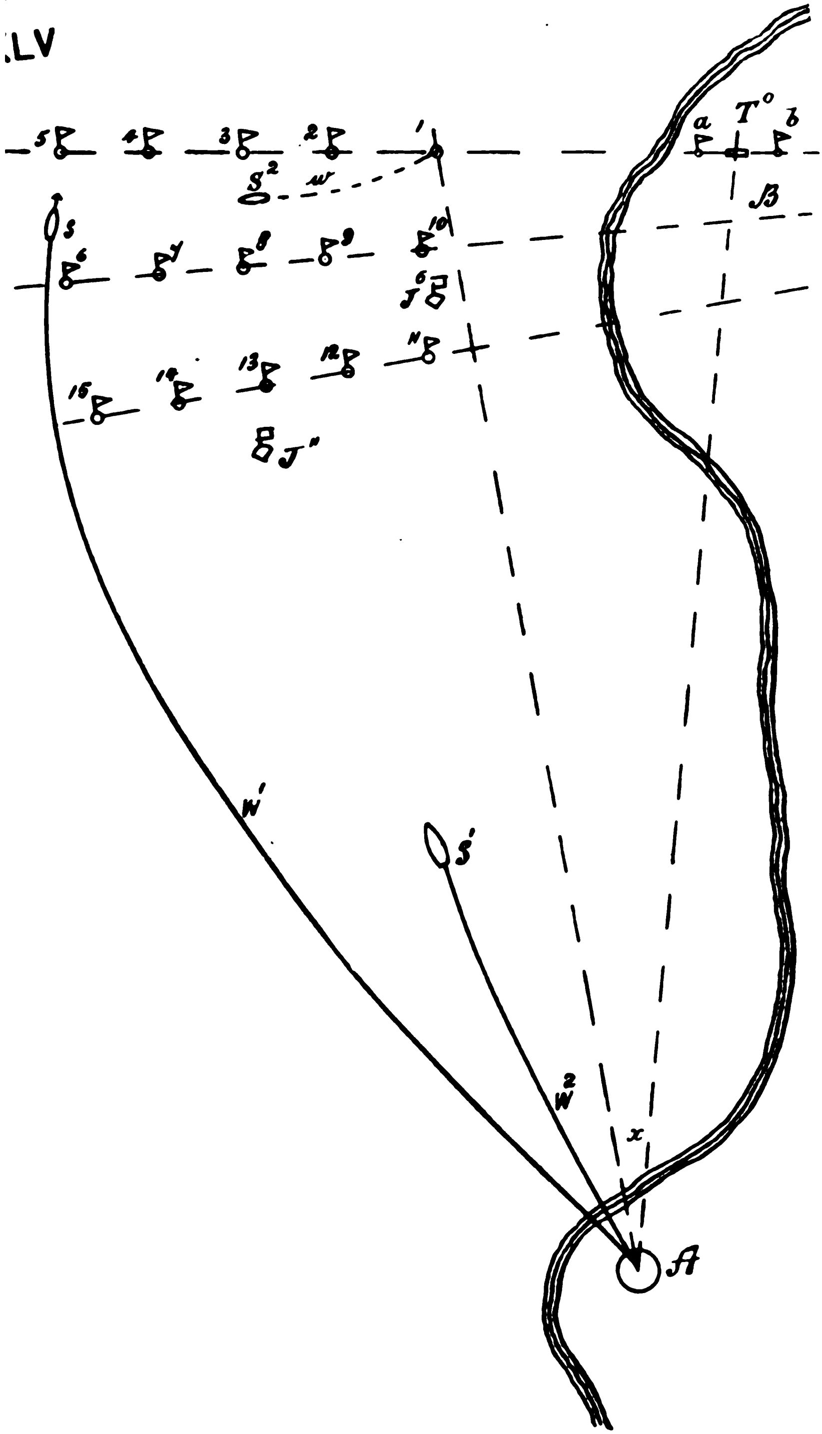
Planting Mines Fired by Observation.—The placing of observation combination buoyant mines in position is carried out as follows:

A boat with the junction-box on board and end of cable connected is anchored at each one of the junction-box positions, J^1, J^6, J^{11}, corresponding to the number of sets of mines which the lighter is to carry, that is for a 15-mine lighter three such boats, and for a 10-mine lighter two boats, would be required to be in position. The lighter carrying the number of mines complete with sinker, circuit-closer case, and mine cable, she is capable of, is then towed out by a steam tug and anchored in the most suitable position for facilitating the work of transhipping the mines from her and planting them in their right position. One of the small twin screw steamers before mentioned then proceeds to place the mines in position, laying those in the outer row first; afterwards those of the middle and inner.

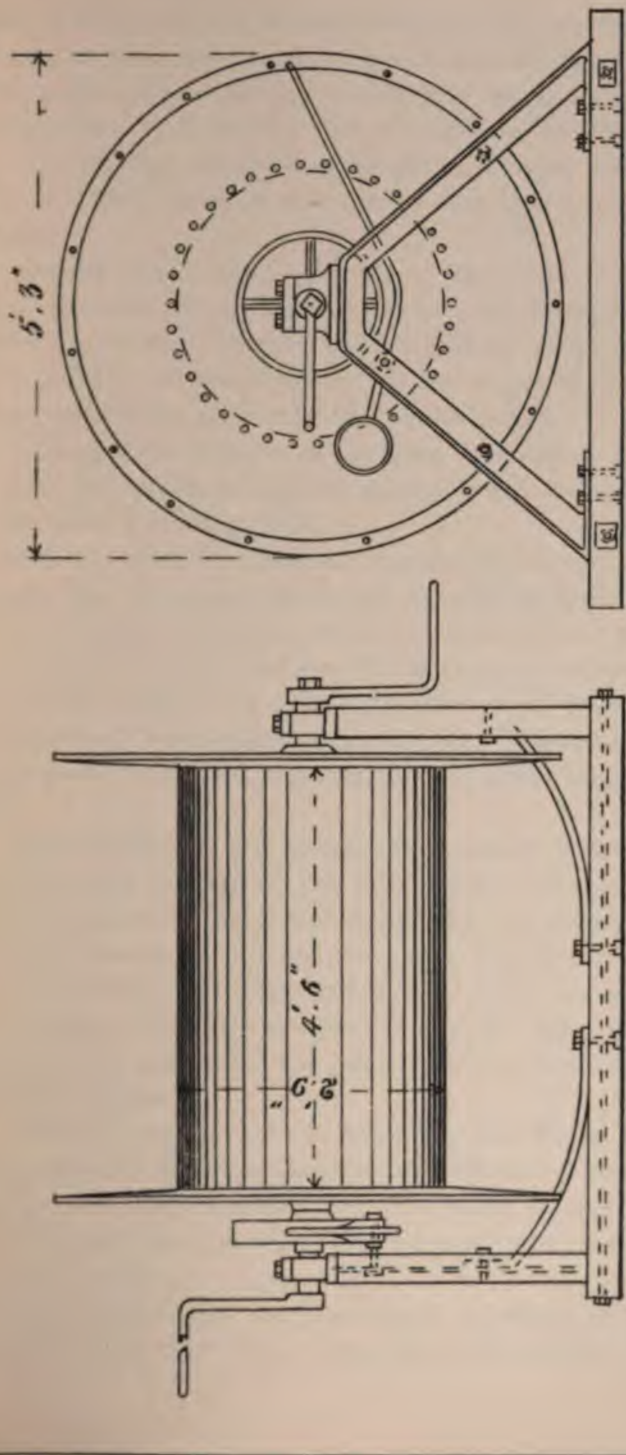
The steamer receives from the lighter a mine and arranged in the following manner:—The sinker, or in the case of a ground mine, the

MOORING OF MINES.

.LV



PL. XLVI



mine itself is hung from the bow by a slip rope long enough to reach the bottom; the mine and circuit closer case, or in the case of a ground mine, the latter only, are slung over the side, the mine cable on its drum being placed in the stern. The mine is hung by a hook spliced into the lowering rope, which by a simple contrivance automatically unhooks itself from the mine or sinker as soon as the latter reaches the bottom.

The steamer thus loaded proceeds to the buoy, marking the position of the mine to be planted, and when in the right direction, determined by the angle between the two stations as given in either Table VI. or VII., and the alignment of the bow on the poles at the converging station, the mine is lowered to the bottom.

The bearing of the mine is at the same time taken at the firing station *A*, a flag which is held up at the bow being dropped the instant the mine is on the ground.

No deviation must be permitted, in planting mines to be fired by observation, from the alignment on the converging station *B* at the moment of dropping the mine, as no correction can be made at *B* for any deviation in this direction; if the mine be dropped with an incorrect angle between the stations the effect would then only be to make the intervals between the mines unequal. Where time permits, this angle should be correct as well as the alignment before dropping the mine.

The mine being on the bottom, the steamer proceeds to the junction box boat, paying out the mine cable as she goes, and on arriving there passes the end into the boat, where it is tested, and, if the test be good, connected up to the core of the main cable bearing the number of the mine. The other mines of the group are planted in a similar manner. When all the junctions of the mine cables have been made to the main cable the junction box is closed, buoyed, and lowered to the bottom.

Two steamers may be used to plant the mines, one placing its mine in position, at the time that the other steamer is proceeding to the junction boat with the cable of the mine it has planted.

Pl. XLV. represents a sketch of the process of laying down a system of observation mines.

S is the junction boat for the groups of mines in the outer row, Nos. 1 to 5, of which No. 1 mine has been planted; S^2 is the steamer proceeding from the mine No. 1 to its junction boat at S; w is the mine cable; W^1 is the main cable of that group; S^1 is the steam tug laying out the main cable, W^2 for the group of mines Nos. 6 to 10; L is the mine lighter; x the angle subtended at No. 1 mine by the base $A\ T^o$; a and b are the alignment poles of the row $T^o\ c$.

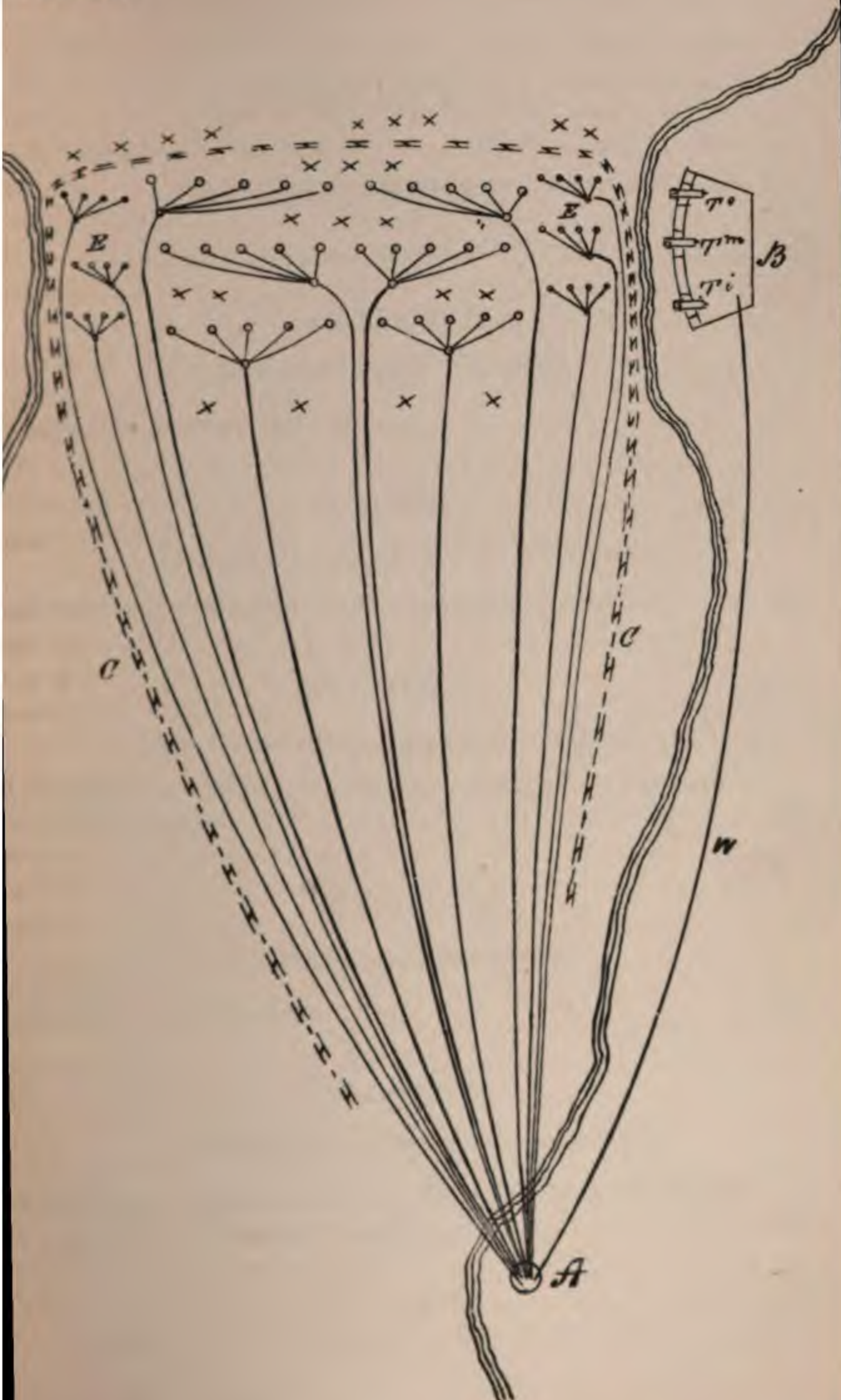
Planting Electro-Contact Mines.—The mines to be fired by observation having been placed in position, the operation of planting the electro-contact mines is then proceeded with.

As the electric cables of these mines are brought to a single junction box for each group, as shown at Pl. XLVII., the process is similar to that described for observation mines, but is more rapidly and easily performed, because the mines and main cables are lighter and of less bulk, and also because the same degree of exactitude in placing them in their positions is not required, as in the case of mines fired by observation.

Other plans for planting a system of submarine mines have been devised and used, but most of them have required special local features of the place where they are to be used to enable them to be executed, while the foregoing plan has been found to be the most suitable under all ordinary conditions.

Description of a General Sketch of the Submarine Defence of the Entrance to a Harbour.—Pl. XLVII. represents a defence of the mouth of a harbour by means of controlled submarine mines, thirty being combination mines arranged to be fired by observation and by contact, and twenty-four being electro-contact ones, showing a mode of protecting the electric cables and the mines against attempts of the enemy to disable them by creeping and sweeping, by means of dummies provided with inverted creepers and chain cables. Six multiple 5-cored electric cables would be required for the combination mines, and six single-core electric cables for the electro-contact mines, supposing only four mines to each junction box in the latter case. A is the main or firing station: B the converging station, where T^o, T^m, T^i, are the converging telescopes for the outer, middle, and inner rows respectively: W, the four-cored station connecting cable, three cores being used for firing the mines, and the remaining core for telegraph purposes; C, C, chain cables to protect the mines from sweeping; E, E, the electro-contact mines; and x, x, dummy mines with inverted creepers.

L. XLVII



SECTION II.

TORPEDOES.

CHAPTER I.

UNCONTROLLABLE TORPEDOES.

CHAPTER II.

UNCONTROLLABLE TORPEDOES—*continued.*

CHAPTER III.

UNCONTROLLABLE TORPEDOES—*continued.*

CHAPTER IV.

CONTROLLABLE TORPEDOES.

CHAPTER V.

CONTROLLABLE TORPEDOES—*continued.*

CHAPTER I.

Uncontrollable Torpedoes.

Projectile, Rocket, Drifting.

1. General remarks—2. The proper application of the Torpedo still unknown—3. Classification of Torpedoes—I. Uncontrollable Torpedoes—4. Definition—5. Defects—6. First defect considered—7. Second defect considered—8. Third defect considered—A. Projectile Torpedoes—9. Early experiments—10. The Projectile *v.* the Spar Torpedo—11. Ericsson's Submarine Gun—12. The theoretical conditions of a perfect one—B. Rocket Torpedoes—13. Definition—14. Commander Barber's, opinion—15. The high power attainable with Rocket Composition—16. Main defect—17. Report on Trials with Weeks Torpedo—18. The Weeks Torpedo—C. Drifting Torpedoes—19. Definition—20. Early History—21. Rarely used now—22. Easily guarded against—23. The Bussière Torpedo—24. Unreliability.—25. Instances of utility.

GENERAL REMARKS.—This section will be devoted to the consideration of the *torpedo* in its many forms, that is to say, of any case of explosive which, by some means or other, is provided with the power of aggression either on or below the surface, and which is primarily intended for the purposes of offence.

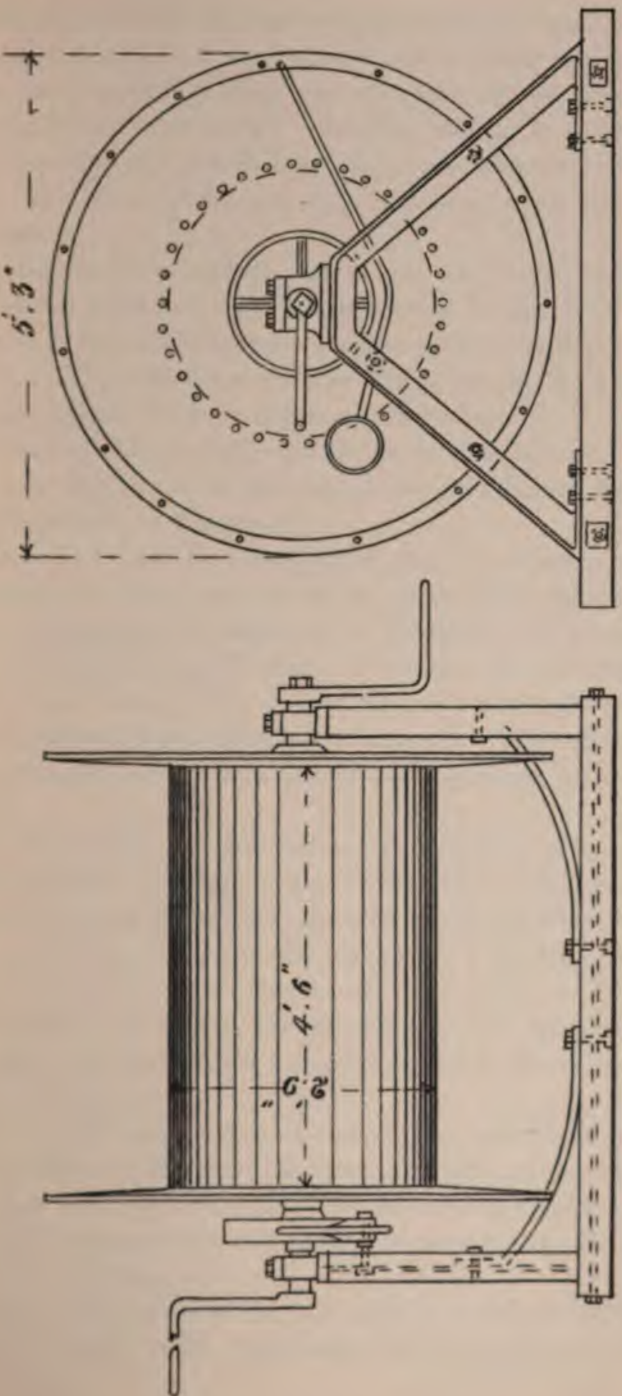
At the present time there are before the world a multitude of inventions of different kinds of torpedoes, and of modifications of some one or other type, of which only a few have received regular adoption; some have failed to realise the expectations of their originators under the crucial test of official trials; others are but just emerging from the difficulties inherent to a realisation in actual practice of a theoretical conception, while some exist only on paper.

It would be quite beyond the scope of a work of this nature to attempt to describe even a tithe of these inventions, and therefore the work of description at length will be restricted to those torpedoes which are in use at the present time, with the addition of a brief consideration of a few others which appear to possess the necessary elements of a successful application in actual practice.

The proper Application of the Torpedo still unknown.—A quarter

MULTIPLE CABLE DRUM.

PL. XLVI



First Defect considered.—The first defect, the most serious one of the three, is inherent in every *uncontrolled* torpedo, because there exists no power which can be automatically applied to such a weapon so as to provide it with the means whereby to alter the course it is set to run on after once it has been started on its way, either for the purposes of correcting a mistake in calculating the speed of the hostile ship aimed at when it is moving across the range, or of the distance of this vessel, or of meeting any sudden alteration in the direction of this vessel after the torpedo has been discharged, or in the event of misjudging the effect of a current, or of the sea, on the course of the torpedo.

Any error in these calculations, or rather experienced guesses, may result, and often has resulted, in the absolute failure of the attack by a mis-shot.

In the case of an anchored target this defect may be minimised in proportion to the speed of the torpedo, and the shortness of the range, provided that the course of the torpedo be not disturbed at the moment of its starting on its run when fired from a vessel in motion; which latter is a cause of inaccuracy not yet eradicated in the "Fish" class, when discharged either from submerged bow, stern, or broadside tubes, or from a gun above the water.

In accuracy of flight the *uncontrollable* torpedo compares very unfavourably with a projectile fired from a rifled gun, because the former lacks the great speed and rotation of the latter, and is besides subjected to more serious causes of inaccuracy; whilst the medium (water) through which the torpedo is propelled is so much more dense than that (air) through which the projectile takes its flight; so that the chances of a successful shot with the former is less than in the case of the latter.

Second Defect considered.—The second defect is caused by the difficulty that exists of knowing with any degree of certainty whether the automatic mechanism has acted by which all *uncontrollable* torpedoes are arranged to be either sunk and rendered inactive, or exploded at will, when it reaches the end of the distance it has been set to run; for, in the event of its missing the object aimed at, should the mechanism fail, the torpedo then becomes a floating charge of explosive as dangerous to friend as to foe, and whose whereabouts are unknown.

That this is no ideal defect is proved by the fact that a number of such weapons (Whiteheads) have been lost in practice by their sinking to the bottom at the end of the run, instead of floating to the surface, as previously arranged for, and therefore the opposite might occur on actual service.

Third Defect considered.—The third defect is a very possible one under certain circumstances, as for instance, in a fleet engagement where, in the excitement of the action, and consequent on the heavy pall of smoke that will usually hang over the scene of the combat, it may at times be a matter of considerable difficulty to distinguish between a friend and foe, and as little time will be afforded for hesitation when an opportunity does present itself for the use of an *uncontrollable* torpedo, where a doubt as to identity exists, the chance of a shot must either be missed, or be taken with all the risks attendant on making a target of a friend.

Both of the latter defects, common to all torpedoes of this group, will most unquestionably tend to limit their application as ship weapons in naval actions.

A. Projectile Torpedoes.

A *projectile* torpedo is a case of explosive projected through the water from a submarine gun.

Though nearly three quarters of a century have elapsed since Fulton's experiments in 1814 with this form of submarine weapon, and though during this period many other inventors have taken up this idea, yet the *projectile* torpedo seems as far off as ever from achieving a practical utility.

Early Experiments.—In 1814, Fulton succeeded with his submarine gun in penetrating a wooden ship's bottom at a distance of 15 feet; in England, in 1864, a Whitworth 24-pounder submarine gun penetrated a 16-inch wood target at a distance of 33 feet; in America, in 1881, Ericsson with a projectile torpedo of 1500 lbs. weight failed on two occasions in striking a target 25 feet by 11 feet at a distance of 285 feet, the projectile in each instance found the bottom in 15 feet of water, the gun being submerged 7 feet; this same invention came to grief when tried in England in 1886, by the premature explosion of its projectile in the bore of the gun.

The Projectile v. *The Spar Torpedo.*—The adherents of the submarine gun claim that it is superior to the *spar* torpedo as a means of offence, because, though its range is very limited, it can be made to strike a ship at a distance, while the latter has practically no range whatever; further, the *projectile* torpedo cannot be stopped by nets of any form, and in this particular it has certainly an advantage over the *spar* torpedo. As regards the question of range alone, it would not seem to matter whether a torpedo vessel armed with the *spar* has to go right up to the ship, or whether, with the submarine gun, it has the power of delivering its attack at some 50 yards distance; in other words, if such a vessel succeeds in arriving at this short distance from the ship to be destroyed, without itself being destroyed, the chances are that she will be able to rush the last 50 yards in safety; when the *spar* torpedo will prove a *surer* means of destruction than the submarine gun at a range of 150 feet, provided that the ship be defended by her guns alone.

The submarine gun labours under a great disadvantage as a means of ship offence, because of the difficulty of ensuring the gun being perfectly level at the moment of its being fired when the vessel has the slightest pitching motion, and if the gun be fired at an angle its accuracy is seriously affected.

The question of *spar* v. *projectile* torpedo resolves itself into a very simple matter, viz. whether either are needed in these days of *Whitehead* torpedoes, and if there are certain phases of war in which it may be thought a needless expenditure of money to use the *Whitehead,* then the simplicity and cheapness of the *spar* torpedo are strong reasons for preferring it to the *projectile* torpedo.

Of course if it be ever possible to bring the range of accuracy of the submarine gun up to that of the *Whitehead,* say 300 yards, it will then become a formidable rival of the latter, owing to its capability of penetrating any known form of ship defence.

Ericsson's Submarine Gun.—The submarine gun devised by Captain John Ericsson will be briefly described, as being the one most recently experimented with both in the United States and England.

The gun:—A breechloading smooth bore, with muzzle firmly secured to the bow seven feet below the surface, and made effectively water-tight; an exterior valve closes the muzzle and prevents the ingress of water before and during the process of loading, and is opened and shut by an elbow lever and a rod passing through a stuffing box; a temporary valve is placed inside the bore close to the former one, and is pushed into its place from the rear, and held there by a spring catch; this valve is intended to be shot away at each discharge, and it has a central hole closed with soft material, against which the firing pin of the torpedo strikes; the projectile occupies the greater part of the length of the gun, only a small space in the rear being left for a piston and for the powder charge.

The projectile:—The projectile or torpedo is built of steel 25½ feet long, 16 inches in diameter, and weighs some 1500 lbs., including a 300-lb. charge; its form is cylindrical in the middle with long pointed ends; four radial wings are fitted to the tail to centre it in the gun.

The disastrous ending of the British experiments with this invention was attributed to the use of a detonator not of the inventor's supplying; but though it was admitted by the British authorities that a delayed action fuze might be used, further trials were declined.

This submarine gun is intended to be mounted in a ship specially designed for fighting bows on at close quarters, and a vessel called the "Destroyer" was built by Ericsson for this purpose, which has been described and illustrated in the previous edition of this work.

Theoretical Conditions of a Perfect Projectile Torpedo.—The theoretical conditions for an effective *projectile* torpedo as stated by Commander F. M. Barber, U.S.N., are briefly—total weight to be equal to displacement, centre of gravity coinciding with centre of figure, large diameter, and great proportionate length with considerable taper at the extremities, and lastly, rotation in the water; with the exception of the latter, all these conditions were practically fulfilled by Ericsson's weapon.

B. Rocket Torpedoes.

Definition.—This class includes all those *uncontrollable* torpedoes which are propelled by the aid of rockets, or some form of rocket composition. This idea of propelling a rocket torpedo on or below the surface of the water is a very old one, dating even further back than in the case of the submarine gun, but both have a common basis of similarity, in that neither of them have so far achieved a practical or even partial success.

Commander Barber's, U.S.N., Opinions.—Commander Barber, U.S.N., in a lecture on movable torpedoes delivered some *fourteen* years since, concludes with the following remarks:

"In conclusion, it may be observed that whether the methods as yet proposed for solving the various problems connected with submarine guns and rockets be feasible or otherwise, it seems probable that they *can* be solved, and that separately or together they may eventually produce remarkable results."

This prophecy has not however yet been fulfilled, though a further fourteen years of experiments with both of these weapons have been carried out.

The High Power attainable with Rocket Composition.—The use of rocket composition as the propelling agent of a torpedo has always been a fascinating subject with inventors, because by means of it the greatest power possible can be obtained, and thus very high speeds attained with the torpedo. For instance, Mr. Quick, R.N., states that a 24-inch *rocket* torpedo can be constructed to exert a propelling energy for eighteen seconds of 3100 I.H.P., a 15-inch torpedo of 1360 I.HP., and a 12-inch torpedo of 760 I.H.P.; while the latest pattern of the *Whitehead* exerts a propelling energy of only some 27 I.H.P.

The Weeks *rocket* torpedo, about to be described, realised a speed of some 45 miles per hour during a *portion* of its official run, which, now that high speed has become a mania with naval men generally, may possibly be a sufficient inducement to inventors to prosecute a further search for a *reliable* weapon of this class.

Main Defect of Rocket Torpedoes.—But it is from the entire absence of this quality of reliability, either in the matter of direction, speed, range, or in the action of the motive power, that the *rocket* torpedo has hitherto so completely failed to establish itself as a practical weapon of offence, and the summing up of the U.S. torpedo Board as to the merits of the most recently tried rocket torpedo (Weeks) exhibits most conspicuously this apparently inherent defect of such weapons, viz. want of reliability. This Board reported as follows:

Report on Trials with Weeks Torpedo.—1st. The torpedo possesses the advantages of simplicity, cheapness, and speed.

2nd. It is fatally defective in accuracy.

3rd. Its speed, at all times great, is very variable (23 to 45 knots).

4th. Its range is insufficient and very variable (300 to 625 feet for single rocket).

In actual service, it has been found impossible to depend on the regular action of the composition, after long storage, and in variable climates, and as is well known, innumerable instances are on record of the premature bursting of rockets in practice either fired above, on, or under the water; whilst they are generally noted for their eccentric behaviour. Of course it is no reason because a particular *rocket* torpedo invention has failed that a practical solution of this problem is not possible, but each succeeding experiment, since its first conception some one hundred and fifty years ago, only seems *to confirm the fact that whether or not it is solvable, this problem of constructing a reliable* rocket *torpedo is surrounded with difficulties, on which up to the present time little or no impression has been made by all the legion of inventors and experimentors who have taken this subject in hand.*

The Weeks Rocket Torpedo.—This invention has been chosen for description, not because it is the most perfect one extant (though it may be), but as representing the latest type that has been submitted to the crucial test of a committee of naval officers well versed in torpedo matters. In the chapter dealing with *Controllable* torpedoes, particulars will be given of the Berdan method of propulsion by rockets.

The *Weeks* torpedo, as experimented with in the U. S. in 1884, was constructed of heavy tin plate, strengthened and stiffened with wood; it was of triangular cross section, with the apex down, so that the ratio of displacement would decrease rapidly with the decrease of immersion due to the burning of the composition. The torpedo was completely decked over and made water-tight. Two fixed parallel wooden tail pieces, or steering rods with small fixed rudders extended astern, for the purpose of assisting the torpedo to keep a straight course, and also by its weight, when lifted out of the water, to counteract any tendency of the weapon to bury its bows. The explosive chamber, intended to hold 75 lbs. of dynamite, extended aft from the bow about one-fourth of the whole length; and in the bow was an air chamber to lift the bow in the event of any tendency to dive.

The rockets used for propelling the torpedoes were each 6 inches in diameter, 3½ feet long, and weighed, inclusive of the iron case, 110 lbs.

Arrangements were made in the larger models for two rockets to be used, the second one to be ignited after the first one has done its work, by the flame of the latter through a bent copper tube.

The rockets were bored out through nearly their whole length, in a line parallel to, but at one side of the central axis. The object of this boring is to secure a uniform burning surface, and consequently a uniform pressure. The burning surface increases until the iron case is reached, then, while the radius of the burning surface increases, more iron is exposed, and a decreasing portion of the cylinder is of rocket composition; in other words the cross section of the burning surface is a circle at the commencement, and so continues until the iron case is reached, when it ceases to be a complete circle; as the radius increases the arc of the circle (angular) decreases.

The torpedo was intended to be fired by percussion, but the only trials made were instituted to ascertain its speed and accuracy.

Five torpedoes were submitted by Mr. Weeks, and thirteen runs were made with them by the Board of torpedo officers, the results of which, and the dimensions of four of these weapons are given in the following tables; the dimensions of the fifth torpedo is not given, but it is said to have differed but slightly from the other four.

Table X.

Type.	Total Length.	Width.	Depth.	Weight.
	feet.	inches.	inches.	lbs.
A.	33	9	12	426
B.	28	12	11	401
C.	37	12	11	529
D.	27½	11	18	597
E.	..	..	..	..
Rocket.	3½	6 inches diameter.		110

Weight of launching apparatus used was 560 lbs.; which consisted of davits arranged to swing the torpedo out clear of the side of the vessel from which it was manipulated.

The rocket was ignited by means of a Farmer magneto-machine, and usually burnt about one second before the torpedo actually started on its run.

TABLE XI.

Date.	No.	Type.	Range.	Speed.	Remarks.
1884.			feet.	knots.	
May 21.	1	..	470	45	Gave off clouds of smoke at starting—sheered broadly to starboard.
" "	2	D.	825	45	Two Rockets—one above the other—straight course.
" "	3	..	500	43	Sheered to port.
" 23.	4	C.	300	..	Sheered broadly to starboard—curve to leeward.
" 26.	5	D.	300	..	Only one rocket in lower space. Missed target by some 250 feet to starboard—vessel under weigh—speed 10 knots.
" 27.	6	..	425	..	Torpedo took a sheer to leeward at first, then rank sheer to windward. Vessel under weigh—speed 10 knots.
" "	7	D.	625	34·5	One rocket. Rank sheer to starboard.
" "	8	D.	480	32·1	Fairly straight for half its run, then rank sheer to starboard—one rocket.
June 24.	9	E.	385	28·8	Sheer to port—angle of 30°.
" "	10	E.	440	28·8	Straight for 200 feet, then sheer of 30° to port.
" "	11	E.	400	..	Sinuous course—resultant straight.
" 28.	12	..	450	..	Sheer of 20° to port.
" "	13	..	500	..	Sheer of 20° to port.

Mr. Weeks has recently altered the shape of his torpedo, devised a new launching arrangement, and arranged his magazine to drop on contact, and explode at any required distance beneath the surface.

In England experiments have been made from time to time to propel a fish torpedo by means of rockets, but the results have not been very satisfactory.

C. *Drifting Torpedoes.*

Definition.—This class includes all those torpedoes which are caused to be carried or drifted to the attack by the action of the current or tide.

Early History.—The utilisation of this force of nature for this purpose forms the earliest record of the employment of what is now termed a torpedo, *i.e.*, a case of explosive possessing the power of aggression, when in 1585 an Italian engineer, named Zambelli, invented a floating mine, and succeeded in destroying a bridge built over the Scheldt by the Prince of Parma. Zambelli's mine consisted of a flat boat filled with gunpowder arranged in it so as to secure its maximum effectiveness, and provided with a long sulphur match rope and clock work for its ignition.

The Drifting Torpedo rarely used now.—Drifting torpedoes of some form or other were originally used to a considerable extent, but of late years little or no attention has been paid to them, probably owing to their having failed to achieve any success in the destruction of ships, and also because of the great strides that have been made during the last twenty years in the development of more efficient weapons for submarine offensive operations.

A torpedo of this class may be readily constructed, and thus lends itself to extempore work, therefore occasions may occur when, in the absence of proper weapons, such as the *Spar*, *Whitehead*, or the *Controlled* Torpedo, even the despised *drifting* torpedo will be found, at least, better than none.

Drifting Torpedoes easily guarded against.—Drifting torpedoes have one fatal defect, in that they can be readily stopped by booms, or nets, in fact a ship's net defence renders her absolutely impervious to an attack of such a nature.

The usual type of *drifting* torpedo can be brought up and prematurely exploded by a floating boom; but there is one invented many years ago by Lieut. Lewis, R.E., which cannot be stopped in this manner, provided that its mechanism acts properly, but is however unable to overcome such an obstruction as a ship's torpedo net.

The Bussière Drifting Torpedo.—In the Franco-German War (1870), Captain Bussière, of the French Engineers, invented a torpedo, which should be drifted along the bottom of a river by the action of the current; its construction was based upon the principle that a spherical body of a weight very little greater than water, and having its centre of gravity coincident with its centre of figure, if placed in the bed of a river will, from its weight and shape, always seek the *deepest* part of the river, that is the bed of the channel, where there are the fewest obstructions and the swiftest and most uniform velocity of current. This invention was expressly devised for the destruction of a bridge at Verdun, thrown across the Maine by the Germans, but was never used; it would escape boom obstructions, but could be easily caught in a net, while the principle of its action seeking the deepest parts would seem to ensure its passing under a ship's bottom, unless she were aground.

Unreliability of Drifting Torpedoes.—Drifting torpedoes must always be more or less erratic in their course, owing to the variable nature of their means of progression, and no dependence can be placed on their action, but where they can be employed in great numbers, some might succeed in causing considerable annoyance and alarm, if not actually successful in exploding in contact with a ship.

Instances of the Utility of the Drifting Torpedo.—There is one phase of war where this class of torpedo might be of great use as a deterrent, viz. in the case of a large body of the enemy attempting the passage of a river in open boats on a dark night; here the constant explosion of such weapons ignited either by contact with the boats, or by automatic clock mechanism, in their vicinity, would probably result in a considerable loss, and at least create a serious panic.

The crossing of the Danube in 1877 by the Russians is a case in point; here was to be seen a large number of open boats of different sizes, literally crowded with soldiers, slowly moving across a broad swift running river on a dark gloomy night, and here, if ever there has been one, was an opportunity for employing *drifting* torpedoes, even of the most crude kind, but the Turks failed to avail themselves of this chance.

Torpedoes of this class arranged to be ignited by clock work or other means a certain time after being launched, and capable of suspending themselves at a fixed depth below the surface might, as suggested by Lieut. Barber, U.S.N., be effective if thrown overboard from the stern of a vessel hotly pursued by another, and though not *drifting* torpedoes in the sense of being drifted to the attack, yet they come under this category, as when once thrown overboard they are adrift.

CHAPTER II.

UNCONTROLLABLE TORPEDOES—*continued.*

AUTO-MOBILE—"*WHITEHEAD*"—"*SCHWARTZKOPFF.*"

1. Definition—2. Reference to Class B.—3. Generic name—4. The forerunner of fish torpedoes—5. The success of the Whitehead torpedo—6. Difficulty of imitation—7. Without a rival—8. Other forms of Whitehead—9. Failure of attempts to imitate—10. Remarks about the Schwartzkopff torpedo—11. History of the Whitehead—12. The Austrian original trials—13. Result of Austrian trials—14. Original trials in England—15. Rapid development—16. Description of the Whitehead—17. Firing apparatus—18. The Balance, or secret chamber—19. The Balance—20. The Pendulum—21. The air reservoir—22. The Servo-motor—23. Propelling engines—24. Sinking valve—25. Lubricating box—26. Starting and injection valves—27. Bevel-wheel chamber—28. After section—29. Bevel-wheel mechanism—30. Length of run adjusting mechanism—31. Horizontal rudders—32. Vertical rudders—33. Capabilities of the Whitehead—34. Methods of using the Whitehead—35. Above-water projection—36. Projection from submerged tubes—37. Comparison of above and below-water discharge—38. Brotherhood's launching tubes—39. Canet's system of discharging the Whitehead—40. Description of Canet mechanism—41. Description of Canet Tube-mounting—42. Defence of channels by the Whitehead—43. The advantages of the Canet system—44. Yarrow's double tube discharge—45. Inaccuracies in practice—46. Torpedo director—47. The Whitehead-Schwartzkopff torpedo—48. Brotherhood's air compressor—49. The Bullivant net defence—50. Remarks on the defence of ships against the Whitehead.

DEFINITION.—This class of *uncontrollable* torpedoes includes those in which the power of propulsion is self-contained, and which, like their prototype the fish, can be run on, or at any depth below, the surface, as may be desired.

Reference to Class B.—In reality the Class B (page 158) type of torpedoes come under this category, at least in so far as being auto-mobile, but the nature of the propelling agent (rocket composition) robs that class of any fish-like properties, and, moreover, has such distinctive attributes as to merit their inclusion under a separate heading.

Generic Name.—The generic name for this class D, and the one by which it is familiarly known, is "the Whitehead," as representing him, who, if not the actual originator of this type, is the inventor of its hydrostatic submerging apparatus, and to whom is due the marvellous commercial success which has followed on its almost universal adoption by the naval powers of the world.

The Forerunner of Fish Torpedoes.—The "Whitehead" is the forerunner of all the auto-mobile *fish* torpedoes that have been conceived, or are in the process of conception; and that the original invention, creating a new class, should have proved so entirely successful during a period of twenty years from a commercial point of view must be accounted as a most remarkable feature, amongst many others, of this invention.

The Success of the Whitehead Torpedo.—In the whole history of the torpedo there is no record of one which, like the *Whitehead*, has become so familiar by name to the general public, whose doings they have so closely scrutinised, and about which so many conflicting opinions and theories have been advanced as to its details of construction and manipulation, more especially in the matter of the so-called "secret"; notwithstanding which only a shadowy notion of what the actual arrangements of the interior of this weapon are, has become common property.*

Difficulty of Imitation.—The German and British governments have certainly succeeded in turning out *Whiteheads*, the former at Messrs. Schwartzkopff's works, and the latter at Woolwich, which are practically equal to those sent out from the inventor's works at Fiume; but this has only been attained by years of industry, the expenditure of vast sums of the public money, and by a treaty of reciprocity as to improvements and modifications devised by one or the other.

Without a Rival.—The *Whitehead* has, up to the present day, met with no rival worthy of its steel, if the so-called "Schwartzkopff" be excepted, though, from all accounts, the "Howell" fish torpedo known by the name of its inventor, Captain J. L. Howell, U.S.N., promises in the no distant future to become a dangerous rival, especially in the matter of accuracy of direction, which is one of the most important essentials of an *uncontrollable* torpedo, and which is somewhat wanting in the *Whitehead*.

Other Forms of Whitehead.—Various forms of an auto-mobile fish

* While though the description of the various parts of the *Whitehead* set forth in this chapter may in some measure dispel this gloom of doubt and hazy conjecture, yet it can never be more than partially effective so long as the descriptive matter is unaccompanied by detailed drawings.

torpedo have been proposed, and patented, and some of them experimented with since the first appearance of the *Whitehead* in 1868, differing from the latter mainly in the matter of their motive power, as, for instance, steam (Hall and Peck), carbonic acid gas (Paulson), and the revolution of a heavy fly-wheel (Howell), in the place of compressed air, each one, however, retaining in principle the leading features of that weapon, but not one has as yet been found capable of equalling, much less of surpassing, the *Whitehead* in the *combined* features of regularity of submersion, accuracy, speed, and range.

Failure of Attempts to imitate.—While, though it is well known that several drawings, said to be complete and to scale, of the *Whitehead* have been offered for sale from time to time, and though many attempts have been made to *imitate* this weapon at private yards, yet all have ended in failure.

Remarks about the Schwartzkopff Torpedo.—The *Schwartzkopff* torpedo, to which reference has been made, is the outcome of the purchase of the secret and right of manufacture of the *Whitehead* by the German Government, but except that the former is constructed of a special material (called phosphor bronze), the composition of which is a secret, instead of steel, there is actually no sensible difference between these two weapons, and therefore it is a moot question whether that one emanating from Messrs. Schwartzkopff and Co.'s Works in Berlin is fairly described by its single appellation of "Schwartzkopff," or whether, in common justice to Mr. Whitehead, who has supplied this Company through the German Government with the information whereby the creation of this offspring has been possible, it ought not, more properly, to be always termed the "Schwartzkopff-Whitehead" torpedo.

History of the Whitehead. — The following brief history of the Whitehead torpedo has been taken from two lectures on this invention, one delivered by Lieutenant F. M. Barber, U.S.N. (1874), and the other by Commander E. P. Gallwey, R.N. (1885); the latter differs from the former only in that no mention is there made as to the originator of the "Luppis" surface automatic torpedo boat.

An officer of the Austrian Marine Artillery, somewhere about 1860, devised plans for the construction of a surface screw boat, to be propelled by either a steam or hot air engine, to be steered from the shore by means of long tiller ropes, and to carry in its fore-part a large

PL. XLVIII

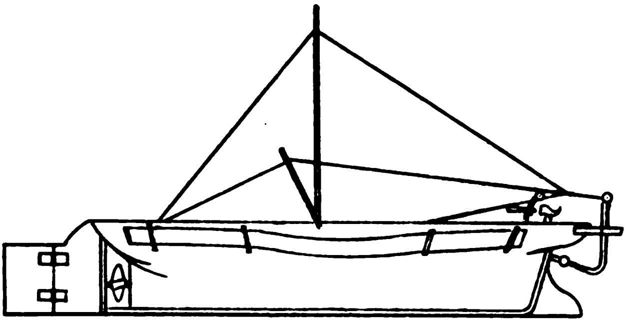


Fig. 1

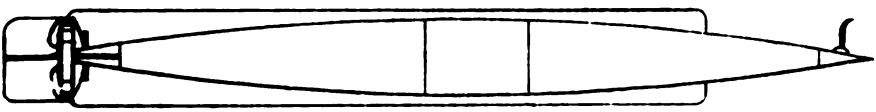


Fig. 2

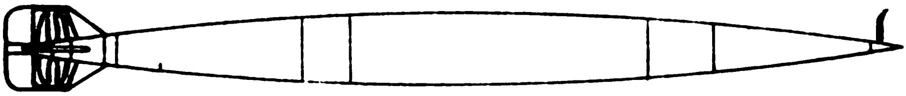


Fig. 3

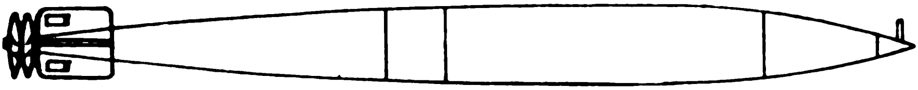


Fig. 4

charge of gun-cotton, arranged to be ignited on contact. On the death of this officer, which took place before he had time to put his ideas into practice, these drawings came into the possession of a certain Captain Luppis, an officer of the Austrian navy, who, being impressed with the notion contained therein, constructed a model to exemplify its mode of action, and by it succeeded in inducing Mr. Robert Whitehead, in 1864, then manager of some iron works at Fiume, to enter into an agreement with him to improve and perfect this idea.

Plate XLVIII., Fig. 1, is an illustration of this model, of what may be called the "Luppis" surface locomotive torpedo boat. It was arranged to be propelled by clock-work, and to be steered by a rudder manipulated from the shore by long tiller ropes. The fore-part was filled with gunpowder, and the ignition of the charge was effected by means of a pistol placed in the head of the boat, the trigger of which was in communication with a movable blade in the bow, and with one vertical and two horizontal spars; either of these arrangements coming into contact with the object aimed at sufficed to fire the pistol and explode the charge.

With this idea as a basis, Captain Luppis and Mr. Whitehead, aided by a son of the latter, *ætat* twelve years, and a trustworthy workman, set to work, and in two years' time succeeded in constructing the first *fish* torpedo. It was made of boiler-plate, and carried a charge of 18 lbs. of dynamite, with a speed of 6 knots for a short distance.

This is but a meagre account of a phase of torpedo history that should be full of interest to all torpedoists, but Mr. Whitehead, to whom the author has applied for a more complete description, and a drawing of *the* first fish torpedo, has not seen fit to comply with his request; it is, however, to be hoped that the complete story of the *Whitehead* will be written some day for the benefit of the future, if not of the present, generation of torpedoists.

The following is a brief general description of the 1867 form of Luppis-Whitehead torpedo (as it was then called), as given by Lieutenant Seaton Schrœder, U.S.N.

It was constructed of wrought iron, and provided with vertical and horizontal blades; it was more of the shape of a dolphin, in the forward part, than a spindle of revolution that it has since assumed. The horizontal blades were used to deflect the torpedo up or down, i.e. above or below a fixed plane of depth, and these were actuated automatically by what was then, and is now, known as the "secret." The motive power was then, as now, compressed air; but the form of motor was not actually known, but a drawing evolved by a Major Daudenard, illustrated in Major Sarrepoint's work, is considered as fairly correct. This drawing shows a cylinder placed eccentrically within another, and in contact with its inner surface actuated and made to revolve round the axis of the outer one by compressed air admitted through a specially contrived valve opening in the circumference of the latter. A sliding plate next to the valve moved in and out at each revolution, always remaining in contact with the inner cylinder, and compelling the air to act always on one side, and in one direction. The propeller was on the central shaft of the outer cylinder, to which the inner was keyed eccentrically.

The Austrian original trials.—The next epoch in the life of this fish torpedo was its introduction to the world in 1868, *i.e.* two years after its birth, on the occasion of its being submitted to the tender mercies of a committee of Austrian naval officers.

The form of the two weapons experimented with by this Commission seems to have been very similar to the present form, see Pl. XLVIII., Fig. 2, only with not quite so great a proportion of length to beam, or with such very full bow-lines as is usual with the more recent types.

The dimensions of the two torpedoes were as follows :—

	Small.			Normal.	
	ft.	in.		ft.	in.
Length	11	7	..	14	1
Max. diameter	0	14	..	0	16
	lbs.			lbs.	
Weight	346		..	650	
Charge (gun-cotton)	40		..	60	

The "normal" type was so called because this was the size of weapon intended for actual use, the smaller one being reserved for experimental purposes.

The trials were carried out at Fiume, and the Austrian gunboat *Genese* was handed over to Mr. Whitehead to fit with a bow ejecting tube. See Pl. XLIX.

This tube was dipped downwards at a small angle with the waterline. The outer end of the tube was closed by a conical door *d* opened and shut by means of a strap-hinge *a* and lanyard; an internal water-tight gate or door *g* was worked up and down by means of gearing *h h*; the inner end of the tube was closed by a third water-tight door *b*. Compressed air was then as now used to eject as well as to propel the torpedoes, and a reservoir of the same in connection with the rear end of the tube was placed in some suitable place near to.

The operation of firing a torpedo out of the tube was as follows: the inner door being opened, a torpedo is entered into its place, and the door reclosed; water is then admitted into the tube by means of a branch pipe *c* from a Kingston valve; both the gate and outer door can then be opened. In admitting the compressed air from the reservoir into the tube the torpedo was ejected with considerable velocity, its engine being started at the same time by the withdrawal of a pin.

The target consisted of the yacht *Fantasie*, protected by a spun-yarn netting about 19 feet in depth, and lowered 6 feet below the surface of the water, and extended along the whole length of the vessel; it was kept in a vertical position by means of heavy stones secured to a jackstay running along the foot of the net. The target thus prepared represented a length of 200 feet, with a depth of 24 feet.

The *Genese* was too small to admit of the tube being more than 3 feet below the surface, while the two torpedoes were intended to be discharged from a tube 12 feet below the surface, and were adjusted to be run at the same depth. Thus the torpedo was called upon to seek its own level, an operation for which it was not prepared. The "small" torpedo was first tried, and out of fifty-four shots only eight were caught in the net; the range was some 700 yards, and both vessels were at anchor.

The variations of the torpedo in the vertical plane ranged from 0 to 40 feet, due to the tube being at a less submergence than what the torpedo was set to run at. Twenty-four shots, or about 50 per cent., passed either into or below the net, the remainder missing the target altogether. The speed of the torpedo was 5·66 knots per hour.

A second series of trials was carried out three weeks later, during which time the inventor had succeeded in adding an improvement by which the oscillations of the torpedo in the vertical plane were very considerably reduced. The certainty of hitting was much increased in these trials, 50 per cent. of the thirty shots fired hitting the net;

while the speed was increased to 6·8 knots. Experiments were also made with the *Genese* moving ahead, and astern, and also with both ships in motion, with satisfactory results. In the latter trial it was found that it requires great practice and correctness of eye to hit a ship moving across the course, at about right angles, of the vessel from which the torpedo is fired.

The "normal" torpedo was also experimented with, and proved to be fairly accurate when ejected from a tube placed at a depth of 14 feet below the surface, for which depth it was set to run at; this weapon attained a speed of 6·7 knots per hour.

The Commission, in their report, summed up as follows:—

1st. The exploding power of 40 lbs. of gun-cotton is quite sufficient to sink any ship.

2nd. The certainty of hitting is as great as can be expected from such an arm.

3rd. The apparatus for firing never fails.

4th. The velocity is indeed not great enough to catch a fast-going ship in a chase; but it is quite sufficient for the defence of harbour entrances, and for the attack of ships at anchor; and as ramming is now the principal mode of attack in naval battles, and they therefore become nothing short of a *mêlée*, torpedoes can even then be employed with great advantage.

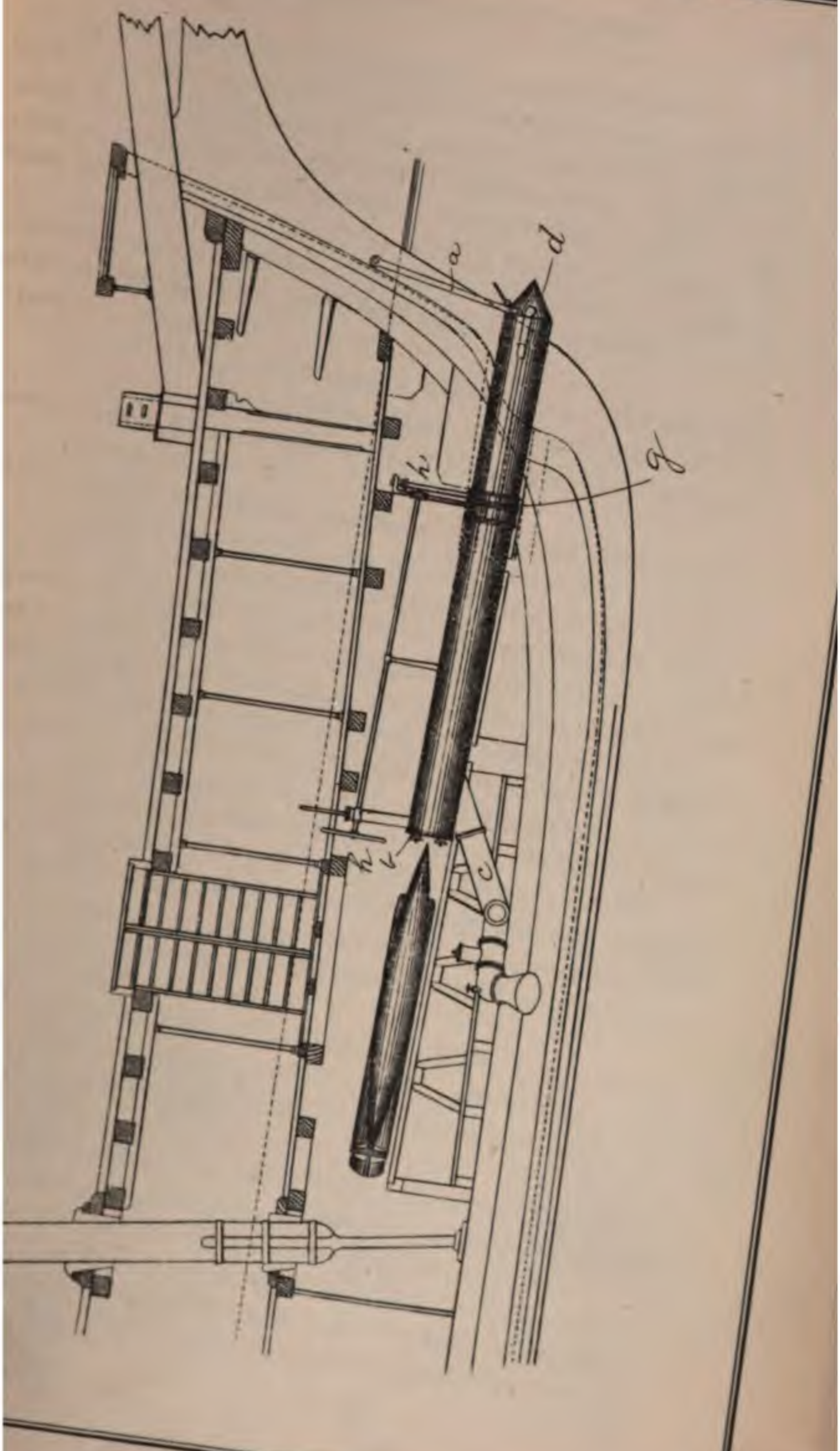
The Commission, therefore, voted unanimously for the acquisition of the secret.

In considering this very favourable and fortunate verdict it must be borne in mind that the only torpedoes known at that time were the *spar* and the *towing* torpedoes; that the battle of Lissa had just been fought; that the speed of the first-class ironclads was then some 12 knots; and that the strongest ships afloat at that time would rank but as fourth class vessels in the present day. While the presence of a SECRET, and the high price charged for its acquisition acted as a strong incentive to purchase, and once purchased, a further expenditure of money to improve and perfect the weapon followed as a natural sequence.

Looked at in the light of the present day, it seems a most extraordinary piece of good fortune for Mr. Whitehead to secure the adoption of his invention, by the Austrian Government, in its then most imperfect and crude condition.

THE LUPPUIS–WHITEHEAD LAUNCHING T

PL. XLIX.



PORTSMOUTH.

Result of Austrian trials.—The adoption of the *Whitehead* by the Austrian Government in 1868 induced other naval powers to consider the advisability of following in her footsteps, and in 1870 this, then wonderful, weapon was brought over to England at the request of the British Government for the purpose of demonstrating to a naval commission its capabilities. These trials being deemed satisfactory, the secret and right of manufacture of the invention was purchased by the British Government in April 1871 for the sum of fifteen thousand pounds.

France, Italy (1873), and Germany followed suit. And now, with the exception of the United States, there is no naval power of any consequence that does not possess the *Whitehead*, or the *Whitehead-Schwartzkopff* torpedo.

Lieutenant Barber, in his lecture of 1874, gives the following interesting particulars of the early history of this invention.

"In 1869 Mr. Whitehead offered his invention to our Government (U. S.) for 20,000*l.*, and in 1874 it was again offered, but as yet (1875) it has not been deemed advisable to purchase it . . . only a few months ago (1874) an offer was made to the Chief of the Bureau of Ordnance by a former employé at Woolwich to sell for a moderate sum the secret of the Whitehead torpedo, and to furnish working drawings of the same. The offer was of course declined . . . The Swedish Commissioner, who witnessed some of the earlier trials of the invention, is said to have offered Mr. Whitehead $10,000 for his secret, saying that it was the opinion of his Government that it would cost about that amount to invent a torpedo of the same description. However true this may be, Mr. Whitehead is said to have spent 40,000*l.* in perfecting his invention . . ."

Original trials in England.—The particulars of the Luppis-Whitehead torpedo tried in England in 1870, and the results of the experiments carried out with it by the British Naval Commission, are briefly as follows:—

This torpedo, shown in Pl. XLVIII., Fig. 2, was constructed of thin wrought iron, and in form cigar-shaped; it was fitted with a projecting plate on both top and bottom, extending about two feet to the rear; also with two small projections on each side, for the purpose of keeping it straight in the submerged tube through which it was projected. The body of the torpedo contained a reservoir of compressed air, and a pneumatic compound oscillating engine, working a *single* propeller.

Two torpedoes of the following dimensions were tried:—

	Large.			Small.
	ft.	ins.		ft.
Length	14	0	..	13·875
Diameter	0	16	..	14 ins.
	lbs.			lbs.
Charge	67		..	18

The torpedo was arranged to be exploded on contact with the enemy by means of a percussion fuze.

H.M. paddle steamer *Oberon* was fitted with a submerged tube under Mr. Whitehead's supervision, who also personally conducted all the trials.

Seventy-five shots were fired from the *Oberon's* submerged tube, seventeen from the surface, and nine from a frame attached to a boat's keel, at submerged targets, on the results of which the Committee summed up as follows:—

Speed.—For short runs of less than 200 yards 8·5 knots. Up to 600 yards, 7 to 7·5 knots.

Accuracy.—A ship at anchor may be struck with tolerable certainty, end on, up to 200 yards. Broadside on, up to 400 yards.

In a strong tideway no practice should be attempted beyond 200 yards.

Ships moving at full speed cannot be struck with any certainty except at close ranges.

The motive power machinery, and the arrangements for charging, projecting the torpedo, and for lateral and vertical accuracy were deemed satisfactory. They further stated that considerable care is required to prevent any damage to the exterior parts of the torpedo.

Rapid development.—The acquisition of the *Whitehead* by the Austrian, British, and other Governments was the means of very rapidly developing this weapon, especially in respect of its speed, and consequent accuracy of direction, and length of range.

The following Table shows the rate of progress during the last twenty years:—

At Pl. XLVIII., Fig. 3, is shown a sketch of the 1877 model, and at Fig. 4 of the 1884 model.

TABLE XII.

Date.	Dimensions.	Speed.	Range.
	ft. in.	Knots.	Yards.
1868 (Austrian)	11½ × 14	5·7	650
" "	14 × 16	6·7	650
1870 (English)	14 × 16	8·5	200
1872 "	14 × 16	8·0	400
1873 (Germany)	14 × 14	17·0	200
1874 "	14 × 14	18·0	200
1876 (Denmark)	14 × 14	20·0	200
1877 "	14 × 14	20·0	600
1881 "	19 × 16	21·0	830
1883 "	9½ × 10	21·0	433
1884 (Browne)	14 × 14	21·0	600
" (Woolwich)	14 × 14	24·0	600
1885 (Fiume)	14 × 14	25·0	433
1887 (Woolwich)	14½ × 14	27·0	400

The principal improvements effected in the mechanism, &c., which have together led to its present high state of efficiency are: 1st. The adoption of the well-known Brotherhood three cylinder engines: 2nd. The introduction of a servo-motor to work the horizontal steering rudders, by which a rapid series of slight movements are imparted to them, or in other words, the power is served out as required, instead of by one complete stroke; this improvement at once reduced the violent oscillations in a vertical plane, and permitted of a uniformity of submergence during a run, quite unrealised with the earlier patterns: 3rd. The use of two propellers revolving in opposite directions on the same line of shafting; this idea of two such screws were first devised by one of the employés in the Whitehead manufactory at the Woolwich Arsenal; this was a most important improvement, as it eliminated almost entirely the tendency of the torpedo to roll, which must result in such a weapon from the use of a single screw; this enabled the topedo to run a much straighter course than had before been possible; because if the torpedo failed by any cause to maintain an upright position during its run, as for instance in rolling, the horizontal diving rudder would then become a horizontal component tending to alter its direction: 4th. The improvement effected in the construction of the motive power (compressed air) reservoir, brought about by the development of the steel manufacture, which enables a greater pressure to be used in a lighter reservoir: 5th. The introduction of double throttle valves, by which the leakage of the motive power is considerably reduced: 6th. The shape of the hull, a full entrance with a very fine run, which has been found to give an increase of speed, and has been adopted not alone for that reason, but because it adds to the displacement without increasing the weight of the torpedo, and also brings the centre of the charge and explosion further forward, *i.e.* nearer to the point of impact.

Description of the Whitehead.—The following description of the *Whitehead* torpedo, though sufficiently complete for the purposes of any one desirous of understanding the nature of this celebrated weapon, yet hardly suffices, and is not intended so to do, for the purposes of construction.

The torpedo may be considered to be divided into eight parts or sections.

The parts are as follows:—

1. Containing the Percussion or Firing arrangement.
2. The explosive or charge chamber.
3. The balance or secret chamber.
4. The air reservoir.
5. The engine chamber.
6. The buoyancy chamber.
7. The bevel wheel chamber.
8. The horizontal and vertical rudders, and propellers.

In describing the torpedo, each section will be considered separately, commencing from the fore end.

Firing Apparatus.—There are two kinds of Whitehead firing apparatus, of which the second described one is now more generally used.

The first arrangement is formed of two castings, screwed one into the other, the front one carrying a nickel-plated steel cylindrical plunger. This plunger has on its fore end four strikers, or whiskers, for ensuring the percussion apparatus being brought into play on the torpedo either striking a net or making impact at an *angle*. A copper washer is fixed by a nut to the front end of the inner casting, which nut has an internal diameter large enough to admit of the passage of a nut screwed on to the end of the plunger. The whiskers are arranged to slide in slots in the front casting. Two holes are bored into the side of the front casting to admit of the introduction of a safety-pin eye-bolt; the object of this safety-pin is to prevent accidents before launching, and is only removed just before placing the torpedo in its launching tube. This eye-bolt is used also in the experimental torpedoes as a means of recovering it.

The whiskers (strikers) are arranged so that, to realise the full force necessary to ensure an explosion, the variation of the torpedo from the line of projection should not be more than about 12°.

The priming case is made of zinc, and contains usually 18 ounces of dry gun-cotton; and the front end terminates in a brass casting, which screws into the main casting, and carries the detonator.

When the torpedo strikes the object with sufficient force, the plunger is driven back, and breaking the copper washer, strikes the foremost end of the detonator (containing the igniting composition), ignites the priming charge, and explodes the torpedo.

The second or improved form of percussion arrangement consists of two castings screwed into each other. The front casting carries a cylindrical plunger, which is bored and screwed to take a screwed piece, the head being similar to the above described plunger, and provided with four vanes. The screwed piece of the plunger is pointed at its after end, and is the actual percussion striker. This is removed, when not in use, for safety purposes, and so dispenses with the old-fashioned safety-pin. When used on actual service, before placing the torpedo in the tube, it is only screwed into the plunger a *short* distance. The vanes are placed obliquely in this case, the object being that the resistance these vanes offer, when the torpedo is projected and is proceeding on its course, will twist the screw-piece right up to striking position, when the plunger is held by a small screwed pin. When the torpedo strikes, the blow causes this pin to be broken, and allows the plunger and screw to be driven up, and strike the fulminating cap of the detonator.

The Balance or Secret Chamber.—The balance chamber contains the mechanism for automatically transmitting the movements necessary for moving the horizontal rudders which maintain the torpedo at a uniform set depth below the surface during its run. It consists of a hydrostatic balance and a pendulum, whose combined movements are transmitted to an air cylinder, called a "servo-motor," with sufficient force and the necessary direction to move the horizontal rudders, and are arranged so that, when the balance is in equilibrium, the torpedo proceeds at the depth for which it has been previously set. In this consists what is known as the "secret" of the torpedo.

The balance chamber is sometimes placed abaft the air reservoir to avoid running pipes through the latter.

A short distance abaft the foremost bulkhead of this chamber is a *partition*, to which the balance or hydrostatic apparatus is affixed, and to this space, termed the ante-chamber, water is freely admitted by means of holes bored in the skin of the torpedo, the air passing out by other smaller holes. These holes are bored at an angle of 30°, as this is found to be the best inclination to admit of water passing freely into the ante-chamber during a run.

The Balance.—In the *partition* of the balance chamber is a circular hole, covered by a dished plate on the after part, and a disc of india-rubber on the fore part, both being bolted together to the partition, thus a *recess* is formed between the covering-plate and rubber disc; a hollow tube (1) forms part of this plate; another tube (2) fits over this tube (1) at its after end, and is so arranged that it (2) can move longitudinally, but cannot turn. At the after end of this covering tube (2) is fixed a boss and three arms, to each one of which is attached a powerful spiral spring.

In the *recess* formed by the covering (dished) plate, a metal disc, called the "Hydrostatic plate," moves easily, and affixed to which is a third tube (3), working longitudinally inside the first tube (1); the solid head of this third tube (3) passes through the covering-plate, hydrostatic plate, and rubber disc, ending in a square head to which to apply a key for the purposes of adjustment.

In the inner end of the third tube (3) a screw-thread is cut, screwed into which is a rod terminating in its after end in a square piece fitting into a square hole in the inside part of the boss carrying the three spiral spring arms. To adjust these spiral springs, *i.e.*, to compress or extend them, it is only necessary to turn the inner tube (3), by which the screwed rod is forced to move *longitudinally* in one direction or the other, according to the direction in which the tube (3) is moved; for, as has been before explained, the boss in which this screwed rod fits cannot be turned round, but has only a longitudinal movement.

The amount of compression or extension due to the depth at which the torpedo is to be maintained during its run, is calculated by actual experiment, and is one of the most important and delicate adjustments of this torpedo, as the tension of the springs must correspond exactly with the pressure on the hydrostatic plate for any particular depth.

The actual portion or number of turns to be given to the inner tube (3), by which to adjust the springs for any depth, is registered on a dial.

When the torpedo is submerged, the water enters the ante-chamber by means of the afore-mentioned holes, but cannot pass into the recess. The pressure of the water, increasing with the depth, acts upon the hydrostatic plate, which, by means of the arrangement above described, and if *greater* than the pressure of the set depth, *overcomes* the tension of the springs, and moves in a direction opposite to that of the torpedo. The tube attached to this plate (3) carries a small arm, and communicates such movement to a lever connected with a rod, which rod is consequently moved in the opposite direction of the arm. This rod is fixed on the other end to a rocking lever in connection with the pendulum, from which another lever (the servo-motor lever) passes through the air reservoir, and connects to the valve of the servo-motor, thereby operating it, and so causes it to act upon the horizontal rudders, inclining them downwards, the action of which lifts the torpedo until the balance is again in equilibrium.

If the pressure be at any time *less* than that of the set depth, the opposite action takes place.

The Pendulum.—The pendulum consists of a heavy iron weight, curved to correspond with the circular section of the torpedo, and suspended by two pivoted steel rods or arms.

The movement of the pendulum is limited both fore and aft by blocks, and a spindle and spring arrangement fitted in recesses cast on the body of the weight.

These springs are used to prevent the weight straining the mechanism when the torpedo is first started, but they are not strong enough to interfere with the working of the pendulum. In some patterns this pendulum is held in a clutch until the engines have made a certain number of revolutions, when the clutch is released.

On the suspension arm is fixed the centre-pin supporting the afore-mentioned rocking lever.

Thus it is seen that the servo-motor, and consequently the diving rudders may be operated either by the increase, or decrease of pressure on the "Hydrostatic plate," due to any variation in the depth at which the torpedo is running above or below the normal or set depth of run, or they may be moved by the swing of the pendulum forward or aft, according as the torpedo is inclined downwards or upwards. When the torpedo is projected from its gun, or launching tube, the pendulum swings forward, due to her inclination downwards, causing the diving rudders to be inclined so as to bring her up, and in addition to this action of the pendulum as soon as the torpedo has passed beyond the depth she is to run at, the pressure on the hydrostatic plate becomes greater than the tension on the springs, and consequently both the swing of the pendulum and increased pressure combine to operate the servo-motor, and thus bring the torpedo to her normal depth very rapidly.

Air Reservoir.—The reservoir containing the motive power (compressed air) is constructed of steel, and is cylindrical, 5 feet long by 14 inches in diameter for the 14-foot torpedo, with dished ends screwed and brazed.

The chamber has recesses on its edges, into which at one end the engine chamber, and at the other end, the balance chamber, fits.

It is constructed to resist a pressure of 100 atmospheres, and is tested up to 120 atmospheres.

The copper tube passing through it, in which the rod from the balance to the servo-motor works, is tested up to 120, and has been tested up to 150, atmospheres.

The phosphor-bronze air chamber of the Whitehead-Schwartzkopff has been found to alter in diameter and length under the great pressures it is subjected to, as follows:—

Pressure.	Increase. In diam. inches.	Increase. In length. inches.
75 atmospheres	—	0·022
90 "	—	0·026
100 "	0·24	0·032
120 "	—	0·037
130 "	—	0·039

The Servo-Motor.—The servo-motor is the air engine from which is derived the power to move the horizontal or diving rudders. It is situated in the engine chamber, and forms part of the casting of the propelling engines.

The principal feature of the Whitehead servo-motor is, that the motive power (compressed air) is always on *both* sides of the piston, by which the movement of the piston is rendered slow and steady, in other words, just as much of the power required to move the horizontal rudder is served out as is needed. In the earlier forms of the *Whitehead*, the engine to work the diving rudders was only capable of putting them hard up or hard down, and therefore the movement of the torpedo in the vertical plane was exceedingly irregular, as compared with the regularity attained with the more recent torpedoes.

The motion of the piston (operating) of the servo-motor is transmitted to the diving rudders by means of a rod and system of levers; while the movement of the small piston, which opens and closes the various air ports by which air from the reservoir is admitted to the cylinder surrounding the operating piston, and by which the air already in the cylinder is expelled, is effected by the servo-motor lever in connection with the Hydrostatic balance and pendulum apparatus.

It must be borne in mind that the movement of the *Whitehead* in the vertical plane, due to the action of its diving rudders, is very rapid, owing to the very high speed (27 knots) at which it travels, in combination with its comparative lightness (5 cwt.), short length (14 feet), and fineness of body.

Propelling Engines.—The engines are of the well-known Brotherhood three-cylinder type.

The compressed air, after leaving the air reservoir, passes through the main pipe to a pressure-reducing valve before entering the cylinders; the object of the pressure-reducing valve is to reduce the high pressure of air coming from the reservoir to the necessary pressure required for the working of the engines. For example, the engines may require to be worked at 30 atmospheres only, whereas the air in the reservoir is at a pressure of 100 atmospheres, and the valve reduces the normal to the necessary working pressure. At 30 atmospheres in the engines, and with 1100 revolutions per minute of the propellers, 48 indicated H.P. is developed. The torpedo is started by means of a trigger which projects a little beyond the casing of the torpedo. Its use is to automatically open the starting valve when the torpedo is projected from its launching tube. The trigger, just before leaving the launching tube, is caught by a catch in the tube, which draws it back, when the catch releases itself.

Sinking Valve.—This valve can be connected up with the rod actuated by the length of run mechanism, or it can be disengaged. If it be connected up, *i.e.*, if it be desired to sink the torpedo at the end of its run, then, when the torpedo has run its allotted course, this rod, by certain mechanism to be described, causes the starting valve to be closed, and at the same time opens the sinking valve, by which water is admitted from the engine room into the buoyancy chamber, thereby destroying the buoyancy of the torpedo and so sinking it.

Lubricating Box.—The lubricating box is of cylindrical form, with spherical ends, and fitted with a tube, one end of which reaches to the shell of the torpedo, where a screwed plug is fitted for the purpose of filling it with the lubricating medium, a mixture of olive oil and petroleum.

A little below the filling hole, a small pipe is connected to the starting valve.

When the starting valve is opened, a portion of the air passes through the pipe into the lubricating box by means of the tube; and in passing through the lubricating box into the reducing valve, it carries with it a sufficient quantity of the lubricating medium to secure the lubrication of the engines and servo-motor.

Bevel Wheel Chamber.—In this chamber is contained the bevel wheel mechanism, by which is effected the revolving of the two propellers in opposite directions on the same line of shafting.

After Section.—The after section or rear end of the torpedo consists of bevel wheels for altering the direction of one of the propellers, horizontal and vertical rudders, two propellers, and the mechanism for adjusting the length of run. The end of the shell of the torpedo terminates in a metal casting, into which are screwed two tubes, one in which the rear propeller shaft works, and another smaller one, through which the length of run rod passes.

Bevel Wheel Mechanism.—There are four bevel wheels used: (1) is fixed to the main propeller shaft, to which the *rear* propeller is attached; (2) is fixed to the outer hollow shaft in connection with the fore propeller; (3) and (4) are attached to spindles at right-angles to the propeller shafts, and engage with the bevel wheels (1) and (2). By this means the direction of the forward propeller is made to revolve in an opposite direction to that of the after one; the rear propeller being fixed to the main shaft, and the forward one to the hollow shaft, to which wheel (2) is keyed, and through which the main shaft passes.

Length of Run-adjusting Mechanism.—A toothed wheel gears into an endless screw on the outer propeller shaft. At every revolution of the propeller the wheel moves one tooth, and one complete revolution when the number of revolutions of propeller corresponds with the number of teeth in the wheel. At every complete revolution of the wheel a pin fixed into it lifts an escarpment and moves a second wheel one tooth. In front of these wheels is a spiral spring encircling the propeller shaft and fixed to a covering tube; this tube moves laterally with the spring, and on the forward end is the lug to which the starting valve rod is connected, and at the rear end a short lever. This spring can be forced forward by a suitable key, and the wheels adjusted for any length of run; the adjustment being regulated by an index on the vertical fin. The action is as follows: When the propeller has made the necessary number of turns corresponding to the length of run intended, the pin on the first wheel is brought to bear on the short lever, which, being pressed down, is released, and the spiral spring flies back, carrying with it the tube and rod, which, being fixed to the trigger of the starting valve, closes it, and so stops the engines and the torpedo, at the same time opens the sinking valve, if this valve is connected up.

Horizontal Rudders.—The horizontal rudders are actuated by motion given to intermediate rods connected with the servo-motor.

Vertical Rudders.—The vertical rudders are placed symmetrically, one on each side of the horizontal tailfins and on both upper and lower sides; they are pivoted, and held in position by screws. On the upper side is an index pointer and scale engraved on the fin. The rudders can be moved to any desired position, and fixed in position by a screw.

The object of these rudders is to correct the horizontal deviation from the straight course of the torpedo's run. The cause of this deviation is explained by the different densities of water in which the propellers work, although both are the same diameter and pitch and revolve at the same rate; but the forward propeller works in water less agitated than the rear one, and consequently has greater effect, causing the torpedo to make a horizontal deviation from its true course.

To overcome this is the purpose of the vertical rudders, one of which must be at zero, and the other adjusted according to data arrived at by experiment. A deviation of 1 in 50 is corrected by fitting the rudder at 15°.

This is one of the improvements introduced by Schwartzkopff, the earlier patterns of the *Whitehead* not being provided with this arrangement.

Capabilities of the Whitehead.—The *Whitehead* torpedo is capable of the following operations:—

1. It may be run at any depth between 5 and 15 feet below the surface of the water; the usual depth is 10 feet.

2. It may be set to run for any required distance, but the longer the distance the slower speed, as the normal pressure of the air in the reservoir has to be reduced according to the range.

3. It can be adjusted to stop after having run any required distance.

4. It can be sunk at the end of its run by the automatic action of the sinking valve. This operation would be resorted to in actual war to prevent accidents from a torpedo which had missed its mark.

5. It can be arranged to come to the surface at the end of its run. This operation is used in practising with this torpedo to admit of its being recovered.

The *Whitehead* is naturally buoyant, and so rises to the surface by its own buoyancy on the engines being stopped.

In some forms of servo-motors a spring is provided, which automatically forces the piston up, when the engines are stopped, and the diving rudders down, tending to assist the buoyancy in bringing the torpedo to the surface.

6. It can be started by hand on the surface of the water, and it can also be discharged or fired from a tube or gun, either above or below the surface of the water. It may be discharged from these guns or tubes by compressed air, steam impulse, or by a charge of gunpowder.

Methods of using the Whitehead.—The *Whitehead* torpedo was originally intended to be projected from a submerged tube fixed in the stern of the vessel using it, but its adoption as the armament of boats and special vessels has necessitated in addition its projection from above, and also from the surface of the water.

The latter method is a forced condition, due to the torpedo being used from small boats or those not specially designed for this service, PL. L.

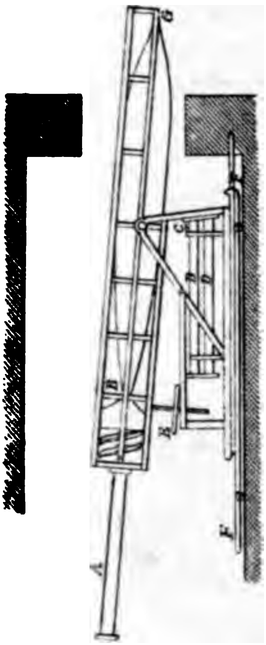


Fig 2.

Fig 1

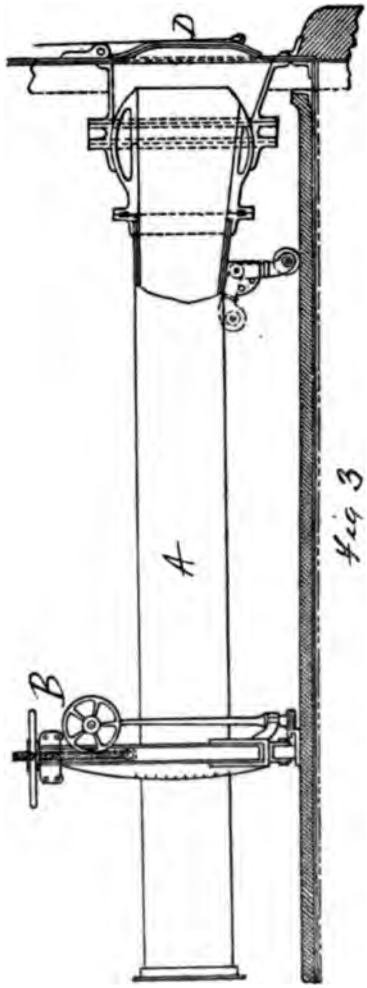


Fig 3

& Co.,

and therefore unprovided with Whitehead guns or tubes. In this case the torpedoes (one on each side) are carried in a light frame hung from davits. When required for use, it is lowered into the water, and started, at a slight inclination downwards, from the boat, the horizontal direction being given by the boat's helm.

Projection from *above* water has been introduced to enable a great number of these torpedoes to be used at the same time from a special torpedo ship, or to provide for broadside firing in an ordinary ship of war, or in torpedo boats which have not sufficient room below for submerged tubes.

Above-Water Projection.—One of the earliest forms of *above*-water projection is shown in Pl. L., Fig. 1, where *G* is a door at the inner end of the carriage by which the torpedo can be entered from the rear, inside of which there is a telescopic piston, to the inner end of which the compressed air is admitted; an impulse tube is fixed to the door. The frame is provided with guides and roller, and has an under lip, some five feet long, extending outside the vessel, by which the rear part of the torpedo is given a slight lift upwards as it leaves the frame, for the purpose of preventing an undue strain being brought on its rear or tail end on entering the water. The air is supplied from a reservoir *D*, *D*, and passes through the stop valve *C* and a valve connected with the handle *B*; this handle also works a stop which prevents the torpedo from slipping out of the carriage.

At Pl. L., Fig. 2, is shown the *over-lip* form of *above*-water broadside carriage.

At Pl. L., Fig. 3, is shown a modern form of *above*-water launching tube. The tube *A* is fixed into the side of the vessel by a ball and socket joint, and is provided with training and elevating gear *B*.

Projection from Submerged Tubes.—The arrangements for launching the *Whitehead* from below the surface of the water are very similar to the foregoing, with the addition of a cap at the outer end of the tube, which can be opened by suitable mechanism from inboard; also a sluice valve to admit water after the torpedo has been inserted and is ready for launching, and to prevent the entrance of water after it has been discharged.

At Pl. LX., Fig. 1, is shown the arrangement of *bow* submerged tube, and at Fig. 2 of *broadside* submerged tubes, adopted in H.M.S. *Polyphemus.* In both figures *A* is the launching tube; *B*, the air reservoir;

C, the sluice valve; and *D*, the drain pipe. The dotted line extending beyond the ship's side shown in Fig. 2 represents the guide bars and shield for the purpose of supporting the torpedo until it is clear of the tube.

Comparison of Above and Below Water Projection.—The *below*-water discharge of the *Whitehead* has the advantages over *above*-water discharge of affording protection to the men in adjusting and manipulating it, as well as to the weapon itself, while the torpedo is less deflected on entering the water, and does not need to be so strongly made; but it has the disadvantage of not permitting of the training of the launching tube, the direction of the torpedo being given by the helm of the vessel.

Above-water discharge labours under the defects of being liable to disablement or the premature explosion of the torpedo by the enemy's fire, and on account of the variability of the height above the water from which it is discharged, caused by the rolling and pitching of the ship or boat, its direction after entering the water is uncertain.

In broadside firing, greater accuracy of direction and less liability to accident is obtained from the *above*-water system of discharge from vessels proceeding ahead at high speeds, the pressure of the passing water, in *submerged* discharges, tending to force the nose of the torpedo aft as it enters the water before the tail has cleared the side, in some instances causing serious damage to the weapon. This defect has been eliminated to some extent by a shield fitted just before the exit port, and extending some distance outside the ship, as shown in Pl. LX., Fig. 2. But as this arrangement has not proved altogether satisfactory, a new method was tried in the spring of last year (1887) on board H.M.S. *Mersey;* the shield and guide bars were dispensed with, and instead, long slits were cut in the skin, the interior space being taperal to the impulse tube to allow the torpedo to be deflected by the pressure of the water without endangering the tail. While the *Mersey* proceeded at moderate speeds, this arrangement worked satisfactorily; but at 18 knots the torpedoes were badly scored, and some were broken up; while those that were launched safely were deflected aft parallel to the keel of the ship, endangering the propellers.

Right astern fire has also been found to be very inaccurate, due to the broken water caused by the ship's propellers.

For tactical reasons, right ahead, bow, broadside, quarter, and

LAUNCHING TUBES H.M.S. "POLYPHEMUS."

PL. LX

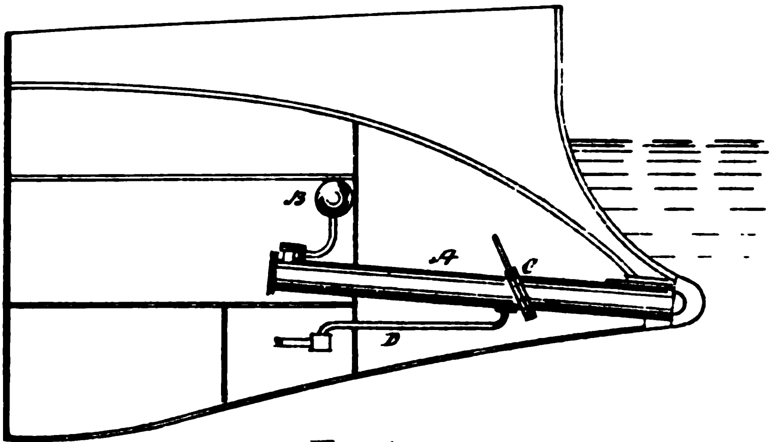


Fig. 1

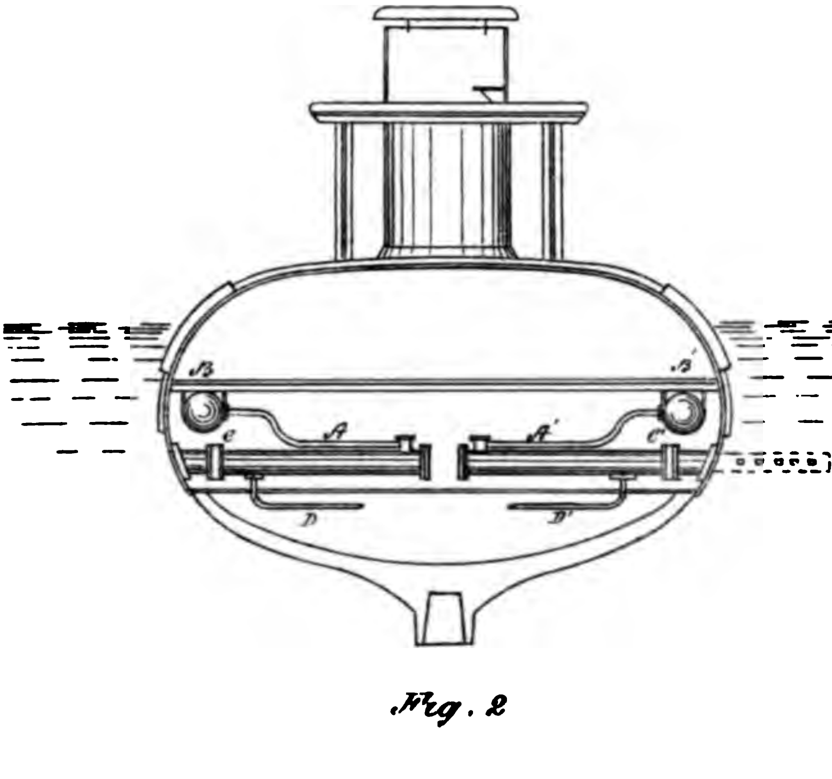


Fig. 2

right astern firing are necessary features of the employment of the *Whitehead*; and when used in ships, for the sake of protection alone, below-water discharge seems an absolute necessity; as however the right ahead below-water discharge is the only one possessing any high degree of accuracy, the *Whitehead* is even now far from having attained that degree of perfection as a naval weapon that its general adoption would warrant.

Brotherhood's Launching Tubes.—The Brotherhood system of discharging *Whitehead* torpedoes *under* water is shown in Pl. LI., where Fig. 1 is a side view, Fig. 2 a sectional plan, Fig. 3 an end view, Fig. 4 a plan of the front part showing the mechanism for working the external guide bar, and Fig. 5 a front view thereof, the side of the ship being supposed to be removed to show the internal construction. Within a stationary cylindrical casing A two tubes B, B^1 are provided, open at both ends, and fixed parallel to each other to two end discs C, C^1, which are fitted to revolve on stationary trunnions c, c, projecting inwards from the ends of the casing A. A shaft D, worked by suitable gearing, has on it pinions d, d^1, which gear with teeth on the discs C, C^1, so that by turning the shaft D these discs, along with the tubes B, B^1, can be caused to revolve within the casing A. When the tubes are in one position, as shown in Fig. 2, a torpedo T, which is laid on a guide trough E, can be pushed into the one tube B through a hole in the one end of the casing A, and another torpedo T^1, which is in the other tube B^1, can by means of a propelling apparatus F be pushed out through a hole in the opposite end of the casing A, which hole is connected by a pipe provided with a sluice valve G to the side H of the vessel. When the torpedo T^1 has been discharged, the tubes B, B^1, are turned half a revolution round their common axis, and the torpedo T in its tube B is thus brought into position for being discharged, whilst the empty tube B^1 is brought into position for receiving a fresh torpedo. On the outside of the vessel is provided a recess in which a guide bar I lies while the torpedo apparatus is not in use. This bar is fixed to an axis i, which extends upwards through a stuffing-box, and has fixed on it a toothed sector gearing with a worm J. By turning this worm by means of a hand wheel j, the bar I is caused to move to the position shown by the dotted lines I^1 in Fig. 2 in line with the discharge tube. The bar I has a groove along it corresponding with a groove in each of the tubes B, B^1, which serves as a guide to the torpedo, a stud on the side of the torpedo passing along this groove.

A pipe *K*, furnished with a sluice-valve *k*, leads from the external water to the end of the casing *A*, into which it opens in line with the tube B^1. This admits water behind the torpedo as it is urged along the tube. A pipe *L* leading to the bilge of the vessel has a segmental opening *l* into the casing *A*, so that when the tube B^1, from which a torpedo has been discharged and which is then full of water, is moving round to the position of *B* for receiving a fresh torpedo, it is emptied of its water by the pipe *L*.

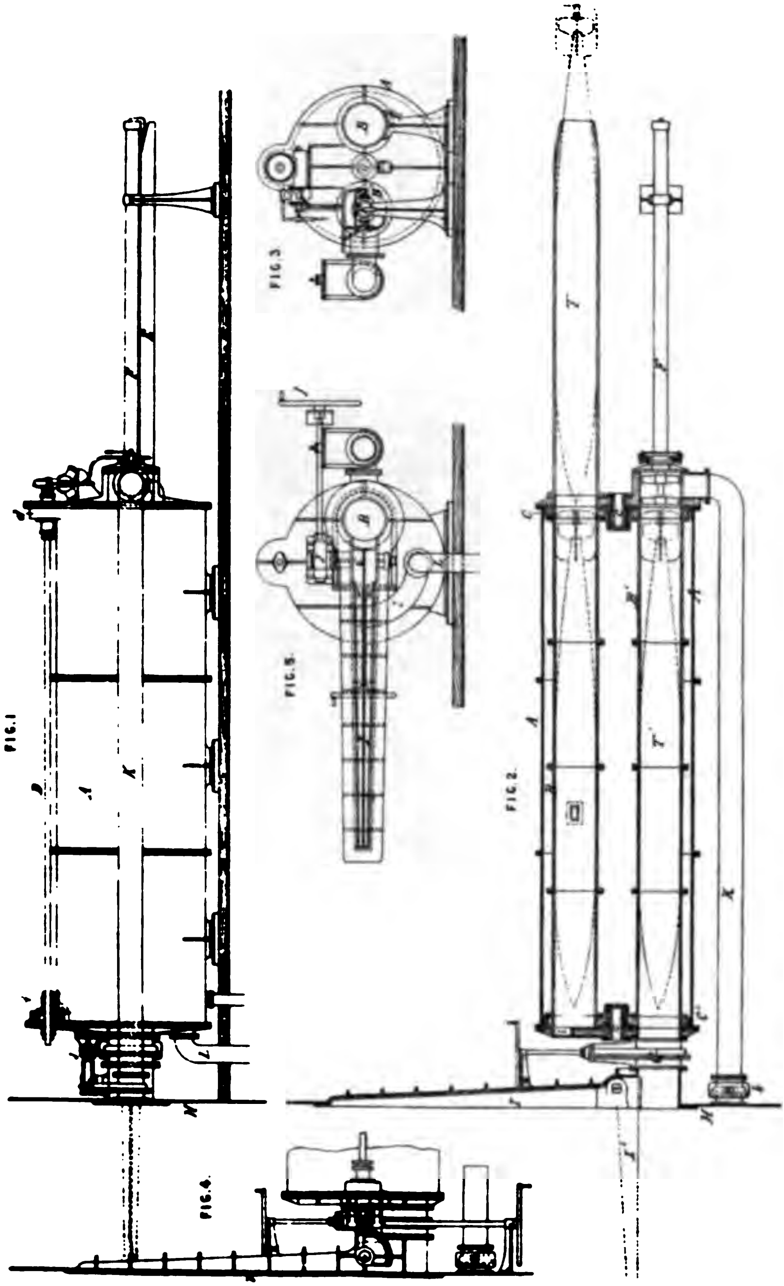
When the torpedo apparatus is not in use, the guide bar *I* is folded back into the recess, and the sluice-valves *G* and *k* may be closed, so that the apparatus can be removed, or access can be got to it for cleansing or repair, all communication with the external water being cut-off.

At Pl. LII. is shown the Brotherhood system of *above*-water discharge for use in ships or torpedo boats.

Fig. 1 is a side view, Fig. 2 an end view, and Fig. 3 a plan of apparatus for launching a torpedo, which is shown at *A*, Fig. 1, as it is placed in the launching-frame ready for being propelled in the direction of the arrow; Fig. 4 is a view from the inside, drawn to an enlarged scale, of part of the upper frame, with the detent or catch apparatus for the middle wings of the torpedo; and Fig. 5 is a transverse section on *Z, Z*, of Fig. 4. A vertical section of the end of the the upper frame, with its catch for the end of the torpedo, is shown at Fig. 6. *B* is the lower frame or carriage, which is pivoted at *b* and is supported on a pair of front wheels or rollers b^1, and a pair of hinder wheels or rollers b^2 running on circular ways, so that the carriage can be trained to various angles of direction. In the carriage are fixed a number of receivers *C*, in the form of strong tubes communicating by pipes with each other, for holding the charge of compressed air. There is also fixed in the carriage *B* a cylinder *D*, fitted with a telescopic piston, the rod of which is attached at *d* to the lower sliding-frame *E*. This sliding-frame is fitted with dovetail guides *e* on the upper face of the carriage *B*, and it has two ears e^1, e^1, embracing side rods e^2, e^2 which have at their front ends helical buffer-springs e^3, e^3. On the upper face of the lower sliding-frame *E* is fitted with guides the upper sliding-frame *F*, having antifriction rollers *f, f*.

THE BROTHERHOOD LAUNCHING TUBE.

PL. LI.



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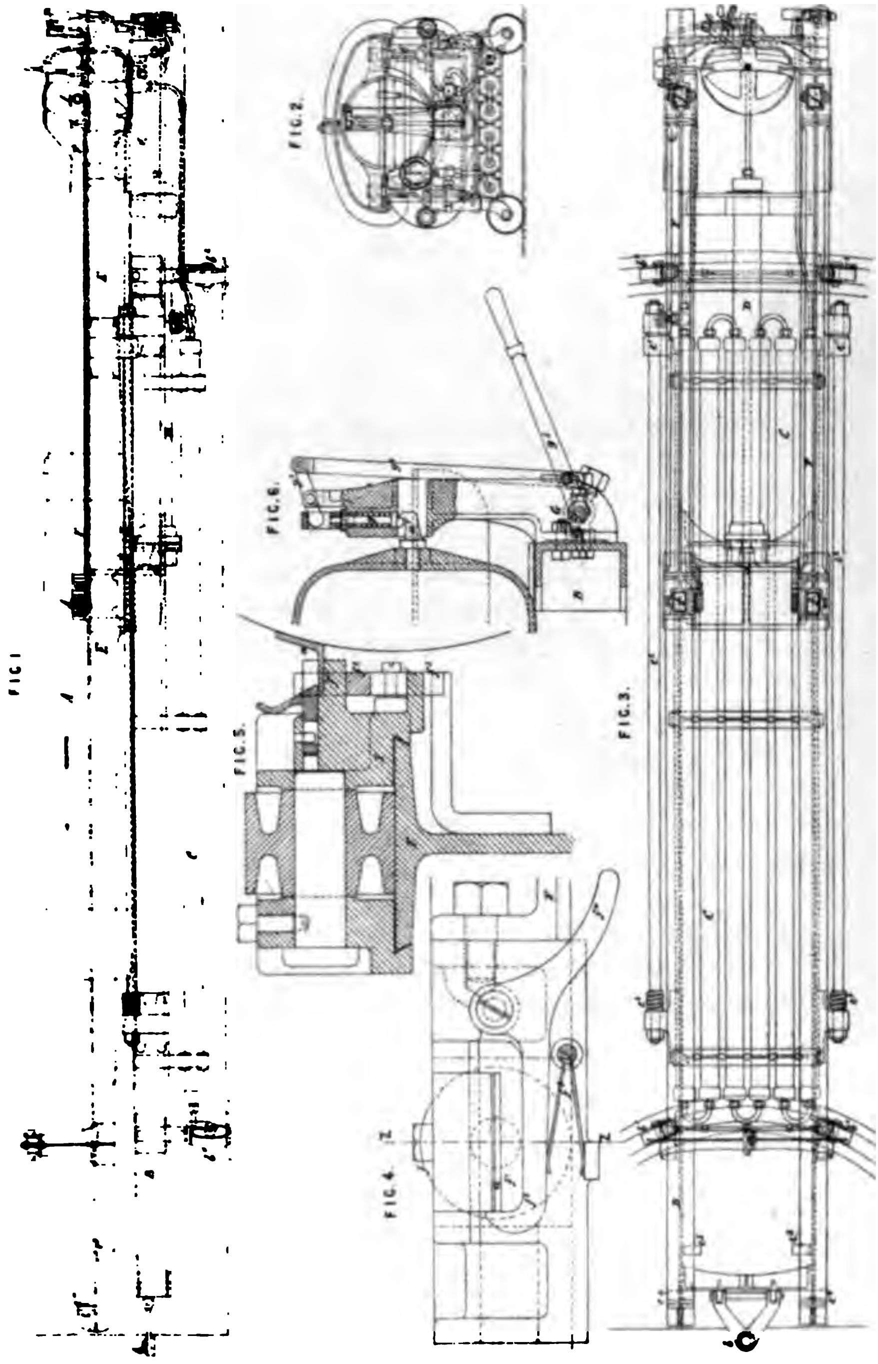
PORTSMOUTH

THE BROTHERHOOD LAUNCHING TUBE.

PL. LII.



& Co., PORTSMOUT

The torpedo has near the middle of its length a wing *a* projecting outwards at each side, and resting on a flange f^1 projecting inwardly from the frame *F*, in which position each wing is held by a catch f^2 that is pressed upwards by a spring f^3, and has a tail f^4, by which it is released, as will hereafter be explained. At the end of the upper slide *F*, which terminates in a cage enclosing the end of the torpedo, there is a hook a^1, which is engaged by a spring bolt *g* fitted to slide in a bracket projecting upwards from the end of the carriage *B*. This spring bolt is connected by a lever g^1 and rod g^2 to the handle g^3 of a three-way cock *G*, which communicates by pipes with the receivers *C*, the cylinder *D*, and a discharge. The connection of the rod g^2 to the handle g^3 is formed by a pin working in a slotted hole, so that it is only during the last part of the downstroke of the handle that the spring bolt *g* is raised.

The operation of the apparatus is as follows:—The torpedo *A* being placed so that its wings *a* rest on the flanges of the upper sliding frame *F*, and that the end hook a^1 is engaged by the bolt *g*, the lower frame or carriage *B* is trained so as to direct the torpedo in the required line of flight. When it is to be launched, the handle g^3 is pushed down, moving the cock *G* so as to admit compressed air from the receivers *C* to the cylinder *D*, and as the handle completes its downstroke it withdraws the bolt *g* from engagement with the hook a^1. The pressure, acting on the piston in *D*, moves it rapidly forwards, propelling the lower sliding frame *E*, the upper sliding frame *F*, and the torpedo *A*. When the lower sliding frame *E* strikes the buffer springs e^3, which arrest its forward movement, the upper frame *F* and the torpedo *A* are carried onward by their momentum, and as the frame *F* approaches stops e^4, e^4, at the end of the frame *E*, the tails f^4 of the catches f^2 are pushed upwards by meeting tappets e^5; the wings *a* of the torpedo being thus released by withdrawal of the catches f^2, the torpedo, in virtue of its momentum, continues its flight.

Canet's System of Discharge.—Hitherto the discharge of *Whiteheads* has been effected by either compressed air or steam impulse, the latter being a special method devised for use in the small (second-class) torpedo boats; but the Canet system of gunpowder impulse, by reason of its great simplicity and cheapness, is gradually superseding both of the foregoing methods.

When first this new system of impulse was introduced, it was thought that it might injure the rudder and other exposed parts of the rear end of the torpedo, but by using a specially prepared gunpowder this trouble has not been experienced, the pressure being reduced to a minimum, and, by a peculiar arrangement of discharge, the gases are distributed progressively and evenly over the circumference of the torpedo.

It was further considered that powder impulse could not be used for firing *Whiteheads under* water, but by securing the following conditions it is as practicable to discharge such a torpedo *under* water by powder as by any other impulse :—

1. The charge must be increased.
2. The charge must be kept dry.
3. The ingress of water into the powder tube after the torpedo has been discharged must be prevented.

Description of Mechanism.—The Canet system of discharge consists of powder impulse, and special forms of torpedo tubes.

The tube is made of bronze or steel. The torpedo is guided inside this tube by means of one or two grooves running parallel to the axis of the tube.

A bolt *b*, Pl. LV., Fig. 1, placed inside the tube, works the starting lever of the torpedo as it is driven out of the tube.

As this starting bolt, which is placed inside a box situated towards the middle of the tube, ought to be often inspected, Mons. Canet has devised a means of quickly closing this box, which ensures its being perfectly watertight, as shown at Pl. LIV., Figs. 1 and 2.

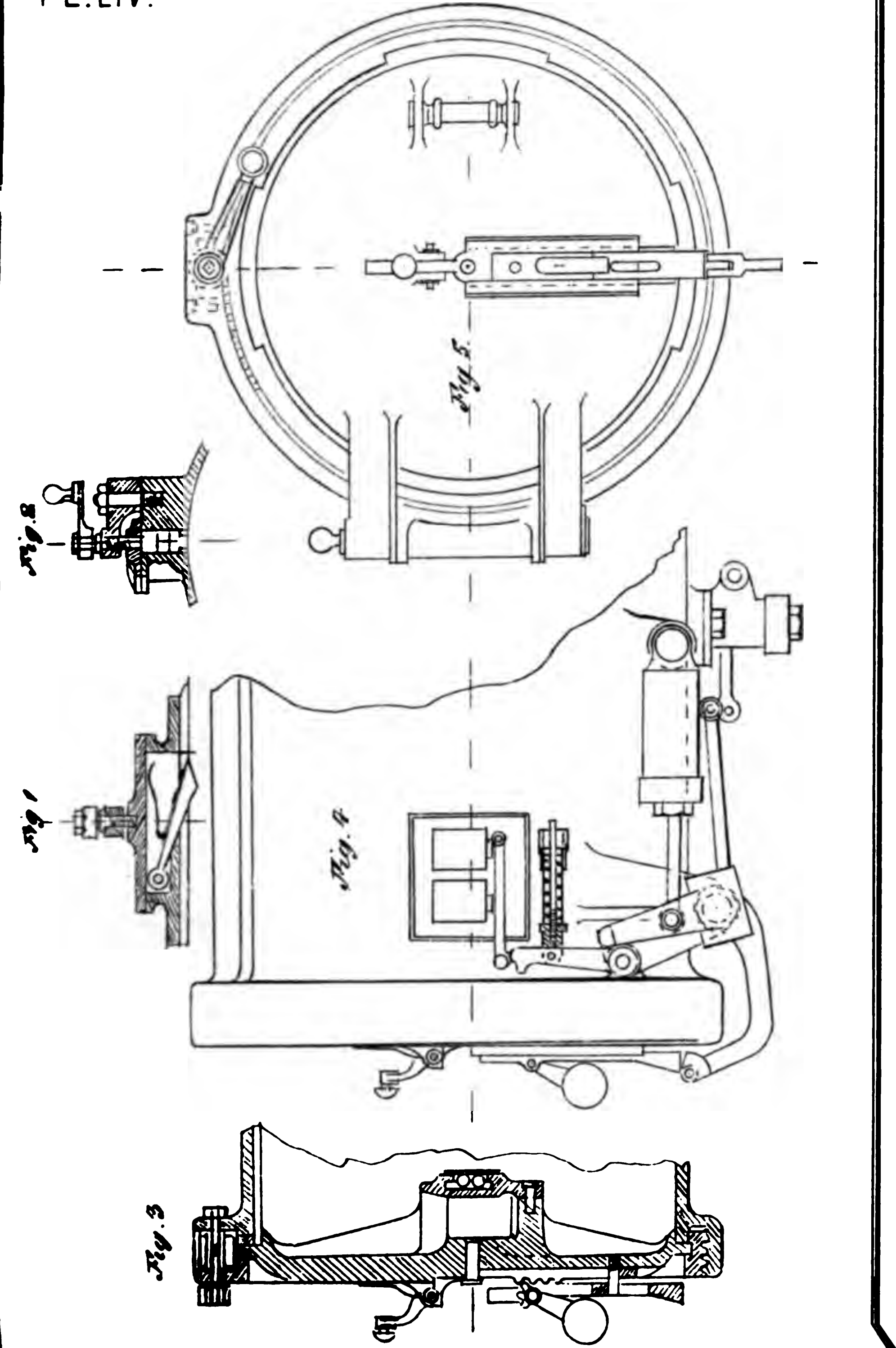
The lid is raised by a coarse-threaded screw, which is worked by a crank-handle or lever.

The female part of this screw is formed by a block of bronze, which is free to pivot on an axis. Half a turn of the screw raises the lid, and the crank-handle is then locked to the block by means of a spring. The crank-handle, continuing to turn in the same direction, slides the block and lid clear of the opening, and the starting bolt is exposed to view and its condition can be inspected.

The reverse of this operation slides the lid over the opening and screws it up as tightly as possible.

A locking bolt in the rear part of the tube bears against the tail-frame of the torpedo, and prevents it from sliding out of the tube when the ship is rolling. Occasionally a second bolt is added to the

PL.LIV.



GRIFFIN & Co., PORTSMOUTH

upper part of the tube, and sometimes also these two bolts are placed on a horizontal plane (at the sides of the tube); and for torpedo-boat tubes, where the vibration is very great, brakes are added, which by pressing firmly against the torpedo render it immovable.

The breach, shown at Pl. LIV. at Figs. 3, 4, and 5, is closed in the following manner:—

The door, working on a hinge at the side of the tube, is secured by means of a movable collar, which is screwed to the hinder part of the tube.

The door is divided on its outer circumference into sectors, some of which are cut away; and the collar has cut on its inside edge corresponding sectors.

By means of a pinion crank and a cog-wheel working on the thread of the collar screw, this collar can be turned and its full sectors brought to bear against those of the door. By a special arrangement this movable collar allows the door to be pressed against the edge of the breech of the tube with a gradually increasing pressure, and the joint is made by a special packing inserted in a groove round the base of the tube. When the door is not connected with the screw collar (movable collar), the pinion crank butts against a stud, which prevents it from turning further.

When the fittings on board a ship do not allow of the use of a pinion crank, or when this crank is hampered by the elevation of the tube, the collar, which is then acted upon directly by means of a lever, can be kept firmly in its place against the tube by a bolt, which is pressed by the door when it is opened.

The cartridge for giving the impulse to the torpedo is of a particular shape, and is made up with a special kind of powder. It is placed in a cavity bored into the inner face of the door, and so arranged that the gases, when the powder is fired, strike the sides of the tube before reaching the torpedo.

The powder chamber is sufficiently large to admit of several charges being used. It is thus possible to increase the charge when necessary, for instance, when there is water in the tube, or when it is required to augment the impulse of discharge.

The charge is fired by means of an obturating percussion tube, which is placed in a vent in the centre of the door. This percussion tube can be removed by means of a claw extractor.

A bolt, sliding in a vertical groove in the breech, carries a hammer, which can turn on a pivot placed on the bolt. This hammer has a toothed tail working into a rack fixed on the door. When the bolt ascends, the rack works the tail of the hammer and forces it against the striker, which at this moment has come on top of the percussion tube.

The firing lever, which acts on the bolt and causes it to ascend, is worked by a strong spring to push it forward.

A catch keeps it in its place until the mechanism is started either by an electro-magnet or by hand.

The locking bolt of the torpedo is worked by a lever fixed to the same spindle as the firing lever. The hammer only strikes the striker when these levers are at the end of their stroke; the locking bolt of the torpedo is therefore free before the charge is ignited.

A stop placed at the bottom of the screw collar projects when the door is not properly closed, and thus prevents the firing lever from working, and consequently the torpedo from being prematurely discharged.

A circuit closer is arranged so that the torpedo-officer can discharge the torpedo from a distance. A bell with an independent circuit informs him whether the battery and circuit are in working order or not.

To prepare the firing gear the springs are compressed by means of a lever working in a socket, and they are kept compressed by a tumbler.

A safety-pin prevents the tumbler from being slipped by accident and the torpedo prematurely discharged.

Description of Tube Mounting.—The torpedo tubes are either fixed, as is the case in the bows of many torpedo boats, or they are movable, as when fitted on the decks of torpedo-vessels, cruisers, and battle-ships.

Fixed tubes for torpedo boats are generally placed in the boats with the fore end slightly depressed and slightly bevelled off.

The torpedo boat should be fitted with a water-tight shield to prevent the water entering the tube, this shield being worked from inboard by a long rod.

The Canet tubes have rather more elevation when placed in the smaller torpedo boats, so that the tube should not be too much depressed when the trim of the boat is altered by the consumption of coal.

"CANET" SYSTEM OF WHITEHEAD DISCHARGE.

PL. LV.

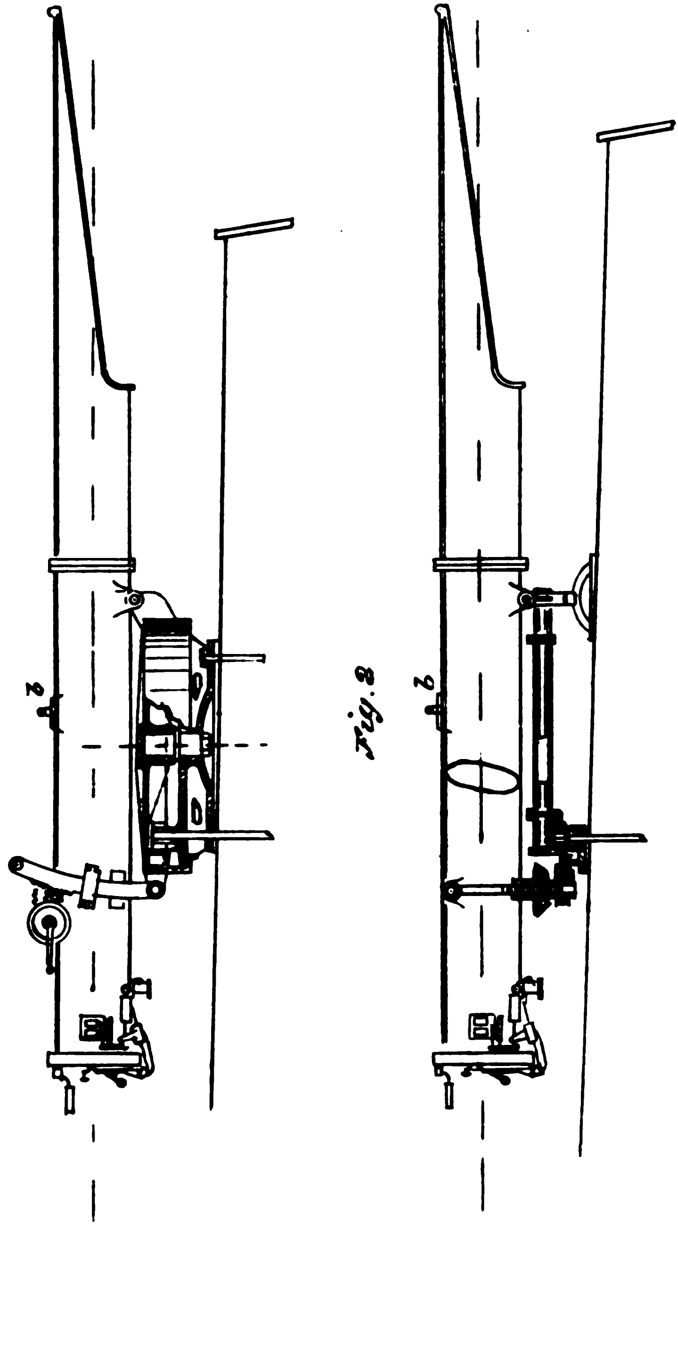


Fig. 1.

Fig. 2.

& Co., PORTSMOUT

The system of firing is the same as that which has already been explained; but, as the boats generally carry two tubes, the firing gear is symmetrically placed on the outer sides of these tubes.

The locking tumbler is generally worked by hand by means of a long rod, which is worked by a lever in a convenient position for the officer in the conning tower.

On board torpedo-vessels the growing tendency is to place the tubes on deck as high as possible above water.

The tube is quite unprotected; but the advantage of being able to discharge a torpedo a-beam, when steaming full speed past the enemy, is considered to counterbalance its exposed condition.

The tubes can be in some measure protected by a steel shield, which revolves with the tube.

The tubes on deck are mounted either singly or in pairs; in the latter case their axes are either parallel or divergent; if parallel, they are fired at the same object with a slight interval of time between the two discharges.

At Pl. LV., Figs. 1 and 2, is shown the Canet method of movable deck-tubes as already fitted on board several torpedo-vessels; the tube, mounted on trunnions, is placed on a platform, which has a circular rack worked by a fixed pinion. This pinion is worked from *below* the deck, and trains the tubes in any direction.

The elevation is obtained by an elevating screw working in a block fixed in a socket in rear of the tube.

As this platform is very heavy, even without the tubes, Mons. Canet has devised an alternative arrangement, as shown in Pl. LV., Fig. 2.

The tube is here supported by a jointed pivot. The rear frame of the tube is connected to the pivot by a hollow rod which hooks to the training circle fixed to the deck. The rear frame carries the elevating screw, and also a pinion worked by a wheel. A cog-wheel at the lower end of this pinion works into the rack of the training circle, and by this means the required lateral training is obtained.

A tube mounted thus on the after part of a vessel has a large angle of fire both ahead and astern.

On board cruisers and battle-ships the tubes are generally movable and placed on the decks or under the beams, according to the most desirable position or the amount of room there is to spare.

The tubes are mounted on a carriage, which is made up of two side-frames bound together by stays. One of the cross-stays has fitted to it a hand-wheel, which works the elevating screw on the tube.

The entire carriage is supported by a frame, which travels on a circular racer fixed to the deck or suspended by the beams.

The laying of the tube is much facilitated by using a multiplying wheel for elevating, which works into an arc on each side of the carriage.

The training for direction is effected by means of a chain windlass or by tackles hooked to the ship's side.

In certain cases a screw stop-bolt enables the tube to be fixed in a required direction.

For firing abeam, spoon-shaped tubes are generally used, as shown in Pls. LV. and LVI.

The cylindrical part of the tube being sufficiently long to admit of the expansion of the gases imparting to the torpedo a sufficient velocity, the upper part is carried on in the shape of a half cylinder, or bevelled, still retaining the original diameter of the tube. This part, called the spoon, is sufficiently long to allow of its supporting the weight of the torpedo until the tail is clear of the tube proper.

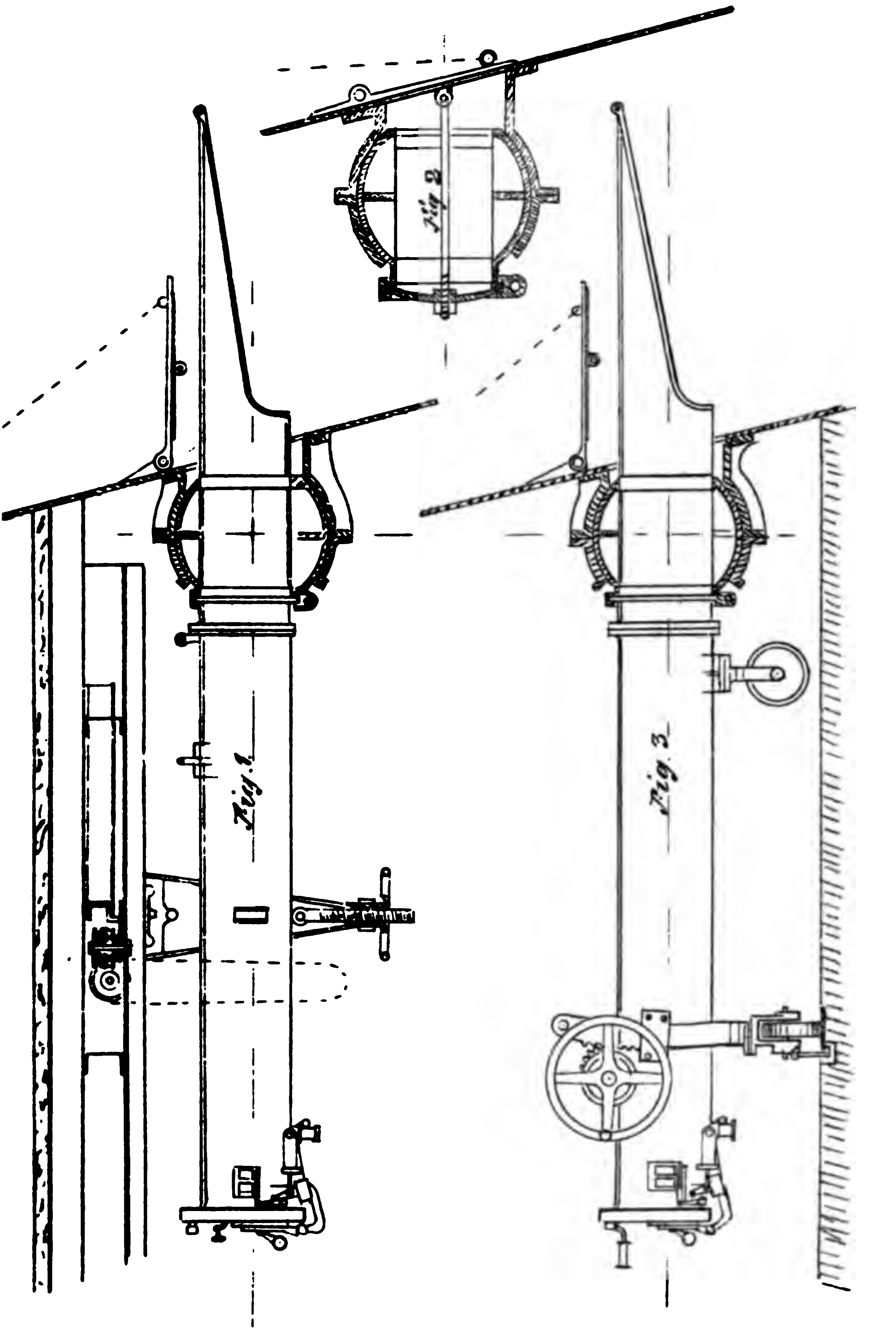
The torpedo is supported in the tube and along the spoon by T-irons fixed on the torpedo in line with its centre of gravity and working in grooves inside the tube. The torpedo thus falls into the water perfectly horizontally.

In cases where spoon-shaped tubes are used, and when on account of the protruding lines of the water-lines of the vessel the tube projects too far from the ship's side, it has been necessary to make a particular fitting to enable the tube to be run in, either for securing it or for inserting the torpedo.

If the tubes are on deck, as in Pl. LVI., Fig. 3, the fore part has a second frame, the rollers of which work in a movable socket, and which permit the tube to be easily trained to the loading or securing position.

If the tube is worked under the beams, as in Pl. LVI., Fig. 1, the rear frame has a transom on it pivoting on the same axis as the tube; the carriage has two rollers, which work on the transom, and the foremost frame also works on this transom. This transom is prolonged by a similar one, on which the tube travels to the loading or to the securing position. This latter transom is itself suspended from the

PL. LVI.



beams by hooks working on rollers, so that the tube can be secured in any position as most convenient.

Mons. Canet's method of fixing the tubes to the ship's side has been planned with a view to obtaining as small a port-hole as possible and a perfectly water-tight joint.

The port should be closed immediately the torpedo is discharged, and kept closed until another torpedo is about to be fired, the crew remaining under cover while preparing the torpedo.

On the fore part of the tube is a spherical disc forged or bolted on to it. This sphere works into a similar hollow sphere, which is fixed to the ship's side in the port. This ball-and-socket joint is so arranged that the tube can be pointed in every direction. A spherical collar is put over the inner part of the disc on the tube, and this collar is connected to the hollow part joined to the ship's side, either by a bayonet point when one-eighth of a turn is required to connect them, or else they are connected by bolts.

M. Canet uses the same sort of attachment-collar, made up of two spherical pieces connected to the piece on the ship's side by means of hinges. The two parts are brought together by a forked bolt, which is clamped over two projecting bolts, and the spherical end of the tube is thus locked in its socket.

When it is required to run in the tube, it is only necessary to disconnect the collar and the spherical part on the tube is free. The tube being run in clear of the side, the port can be closed, as shown in Pl. LVI., Fig. 2.

If it is required to give the tube *extreme* training, it would then be necessary to use a sphere of very large dimensions, in which case the end of the tube is secured to the ship's side by means of a particular kind of (Cardon) collar.

The dimensions of the port can then be even more reduced, though no advantage is gained by this in rendering it more perfectly water-tight.

Tube *frames* are used for torpedoes intended to be started under water without any impulse. They are made of four bronze rods kept in place by iron hoops.

These tubes are placed *outside* boats or ships, and slide up and down on racers specially arranged outside the hull.

The tube, charged with a torpedo, is lowered into the water, and the torpedo can be started by working its starting lever by means of a tumbler on the tube worked by a long rod from inboard.

The tubes are lifted inboard when not in use, so as not to impede the ship's progress through the water.

This tube frame is most useful in adjusting the torpedoes. As this adjustment takes place in harbour, the vertical racers are replaced by a fixed platform, which holds the frame under water. As the torpedo is then started only by its own screw, it cannot be subjected to any outside disturbing cause, and the course it takes will depend on its adjustment.

Defence of Channels by the Whitehead.—The Canet torpedo tube, mounted on a movable carriage of a special type, somewhat like that mounted on the decks of ships, can be usefully employed for the defence of narrow channels and rivers.

The tubes can be easily arranged for mounting on the special carriage.

The impulse being obtained by *gunpowder*, the tube is always ready, and can be transported by land or on a boat to the threatened point. By this means, in certain cases, it might be feasible to dispense with submarine mine defence.

The simplicity and easy manipulation of this weapon permits of its being hastily put into a steam or rowing-boat, when it would be capable of lending efficient assistance in a night attack.

The Advantages of the Canet System.—For the discharge of *Whiteheads* by powder impulse, and the mode of mounting the tubes devised by Mons. Canet, the following advantages are claimed:—

1. The torpedo tube is always ready.

2. The torpedo can be discharged with certainty, even when the firing gear is out of order. It is sufficient to raise the stop-bolt with a lever, and to knock the striker with a hammer.

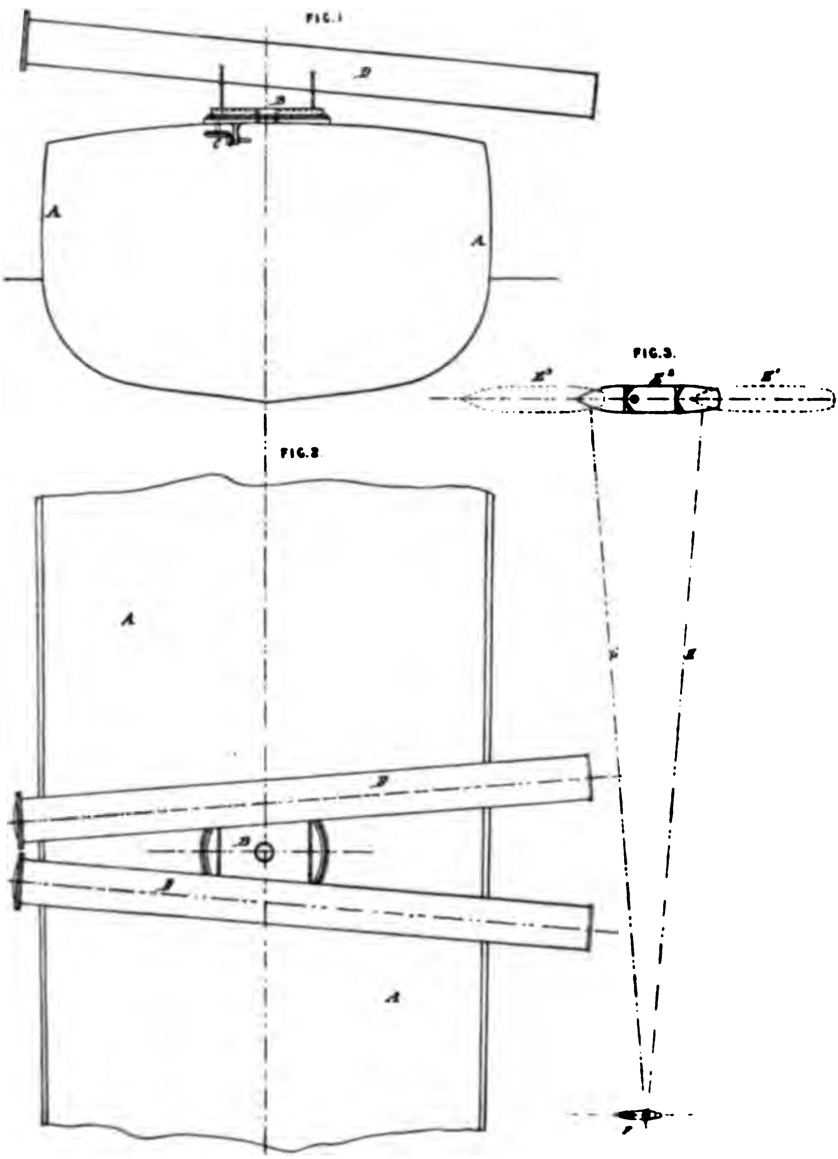
3. A great excess of power is stored up in compressing the spring of the firing gear, therefore the locking bolt is freed directly the circuit closer is pressed, even though it were jammed by the torpedo working on it through the ship's motion.

4. The charge cannot be fired unless the breech is properly closed and the locking bolt raised.

5. The gas of the fired powder cannot injure the rear part of the torpedo, and the manner in which the pressure is distributed enables

YARROW SYSTEM OF DOUBLE TUBES.

III.



heavy charges to be used. This is particularly useful in torpedo boats, where it is necessary to augment the charge on account of the tube and gear being full of water.

6. The working of the breach and other gear is very easy.

7. The obturation is very good.

8. The system offers all the advantages of electric firing (instantaneousness, and enabling the charge to be fired from a distance), together with the advantage of firing with a percussion fuze, which is very sure and never misses fire.

9. The carriage admits of the tube being handled with rapidity and precision.

10. The whole arrangement can be firmly secured in bad weather. The ball and socket arrangement considerably minimises the opening required in the ship's side, and yet allow of extreme training being obtained, while it prevents the entry of water either with the port open and the tube in its place, or with the port closed and the tube run in.

11. The gear is reduced to a minimum, both at the fighting place of the tube and at the securing place.

12. The tube being *run inboard* to be loaded, this operation can be performed in all safety.

Yarrow Double Tube Discharge.—In the larger class of torpedo boats recently built, an arrangement devised by Mr. Yarrow is used for the discharge of their *Whiteheads*, which consists of two tubes mounted on a turn-table, having a slight angle between them; each pair of tubes can be trained through a considerable angle, and if the two torpedoes are fired together the chance of a hit is much increased.

This system is illustrated in Pl. LIII., where Fig. 1 is a cross sectional elevation and Fig. 2 a plan of part of a torpedo boat fitted with launching apparatus arranged to carry *two* torpedoes. *A A* is the boat, upon the deck of which is mounted a turn-table *B B*, which is capable of being turned to any required position by means of the internal wheel and pinion and bevel wheels *C*. The turn-table *B* carries two fixed guns or tubes *D* for ejecting the torpedoes, the centre lines of which guns are shown in plan at Fig. 2 to diverge from each other towards their ejecting mouths at a small angle.

Fig. 3 is a diagram illustrating an attack by a torpedo boat (shown at *F*) fitted with this system of launching apparatus upon an ironclad E^2, say 300 feet long, going in the direction from E^1 to E^3, at, say, 500 yards' range from the torpedo boat. The paths of the torpedoes are shown by the dotted lines *G H*, and show that, by the simultaneous discharge of the two torpedoes, a hit by one of the torpedoes is secured even if a considerable error be made in aim, judgment of distance, or speed of the enemy, for it will be seen the vessel would be hit if in the position E^1 or E^3 or any intermediate position.

More than two launching tubes *D* may be similarly arranged if so desired.

Inaccuracies in Practice.—There are two important errors to which the *Whitehead* class of torpedo is liable to in actual practice, and either of which may occasion a lost shot.

The first error which may occur is in beam firing if the correct deflection due to the angle at which the torpedo enters the water is not allowed.

The amount of deflection of the torpedo will depend on the speed of the ship discharging it, and the velocity of projection when fired against a *stationary* target—the greater the speed of the ship the greater will be the deflection; and the greater the velocity of projection of the torpedo the less will be its deflection. From data obtained from actual experiments a table of deflections can be made out for various speeds. This deflection is usually about one degree per knot of speed of ship.

Two other tables of deflections will then be necessary in the case of a *moving* target—one when the target is moving on a course parallel and opposite to that of the ship, and the other when the target is proceeding on the same course and parallel to the ship.

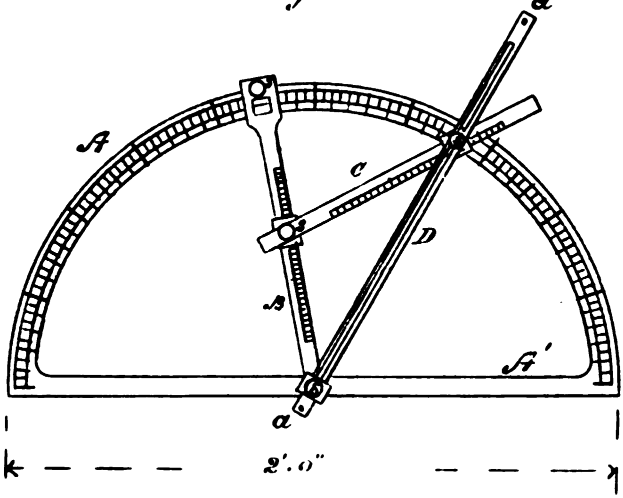
The accuracy of the practice will depend upon the correctness of the estimate of the speed of the target; but as the target (a passing vessel broadside one) presents a large mark, a very considerable error in the estimated speed may be made at short ranges and with high-speed torpedoes, without actually occasioning a lost shot.

A 20-knot torpedo fired at a first-class man-of-war at a range of 300 yards, would permit of a mistake in the estimate of her speed of 3½ knots either way without causing the torpedo to miss.

The faster the torpedo the greater chance there is of a successful shot.

Torpedo Director.—The torpedo director, shown at Pl. LXI., PL.LXI

Fig. 1



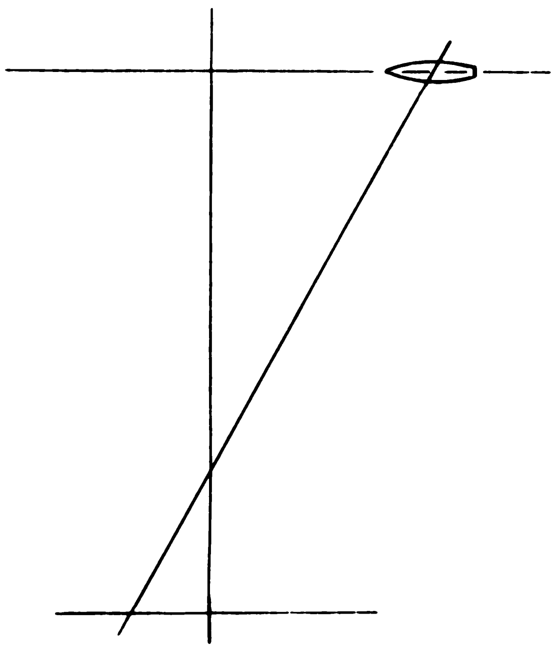


Fig. 2

Fig. 1, consists of a brass semicircular casting *A*, *A′*, faced and graduated.

It is provided with two adjustment bars *B* and *C*, and one directive bar *D*. The bars *B* and *D* are pivoted at *a*, while *C* may be clamped in any position on *B* and *D*; *B* is engraved "Speed of Torpedo"; and *C*, "Speed of Enemy," both being marked in knots. The graduated arc *A* is termed the "Bearing Circle." The direction bar *D* is provided with two sights.

The use of this instrument is as follows: Suppose speed of torpedo to be 20 knots, speed of enemy's vessel crossing the bow 18 knots, and the torpedo to be fired right ahead; then *C* would be clamped on *A* at the 20 mark, on *D* at the 18 mark, and the bar *B* right ahead, this being always parallel to the direction of the torpedo. Then, as soon as the enemy came on with the sights on *D*, the torpedo would be fired, and as the torpedo leaves in the direction of the bar *B*, and the enemy is moving in the direction of the bar *C*, they would meet on the principle of similar triangles, as shown in Fig. 2.

The Whitehead-Schwartzkopff Torpedo.—The *Whitehead-Schwartzkopff* torpedo is almost identical with the Whitehead, differing from it mainly in regard to the material (phosphor-bronze) of which the hull and working parts are constructed.

This weapon is the result of Germany's purchase of the Whitehead secret and the right to manufacture, and is the production of the Berlin Machine Stock Company, formerly J. Schwartzkopff, from whom it takes its name.

The use of this phosphor-bronze material (the composition of which is a secret) for the construction of the *whole* of the torpedo has the one great advantage that it may be kept in a perfect state of adjustment for many weeks either in the depôt, or on board ship, or in torpedo boats, or in a submerged fort, as it does not need to be taken to pieces for cleaning purposes; and this work of cleaning, which is so necessary in the case of steel torpedoes from time to time, involves the readjustment of the various delicate mechanisms, an operation not always satisfactorily performed when the torpedoes are away from the depôt.

Phosphor-bronze torpedoes have been kept for three consecutive weeks in the water ready for running, and at the end of that time have run perfectly.

It is said that the use of this phosphor-bronze material for the construction of the air reservoir has prevented the German torpedo from achieving the high speeds attained by the *Whiteheads* built at Fiume; but this is probably due to the fact that the German Government insists on the attainment of a *uniform* rate of speed for all their torpedoes, with the object of obtaining uniformity in the necessary adjustments for speed, when using them in practice.

It would seem an important feature of success that the *Whiteheads* supplied to every ship should be uniform in the matter of speed and in all other particulars, and one that would outweigh the advantages of an increase of speed in some one or two of them, even if it be a question of even two or three knots. The following particulars show the perfectness which the German phosphor-bronze torpedoes have reached as to uniformity of submergence, and in this they certainly are worthy of imitation.

The results in the following table were obtained with some of the earlier forms of *Whitehead-Schwartzkopff* torpedoes.

The data were obtained by the suspension of nets at the indicated distances, and by the position of the holes made by the passage of the torpedoes; the different depths were measured from the surface.

The torpedoes were arranged to run at 10 feet, and were projected at 5 feet below the surface of the water.

Table XIII.

Number of Discharges.	Depth in Feet.	Depths found at yards from the Tube.					
		22	33	55	82	110	220
114.	Max.	3·6	8·5	8·8	10·0	10·0	10·3
	Min.	3·6	6·2	8·1	9·1	9·1	9·6
	Average	3·6	7·5	8·5	9·4	9·8	9·8
117.	Max.	3·6	4·5	7·8	10·3	10·0	10·0
	Min.	3·6	4·5	7·8	10·3	9·1	8·5
	Average	3·6	4·5	7·8	10·3	9·6	8·8
84.	Max.	3·8	5·9	8·1	10·3	10·9	10·0
	Min.	3·8	5·2	7·2	9·1	10·3	8·8
	Average	3·8	5·5	7·8	9·8	10·5	9·1

Brotherhood's Air Compressor.—Air-compressing pumps for the purpose of charging the air reservoirs of the *Whitehead* torpedoes

PL. LXII.

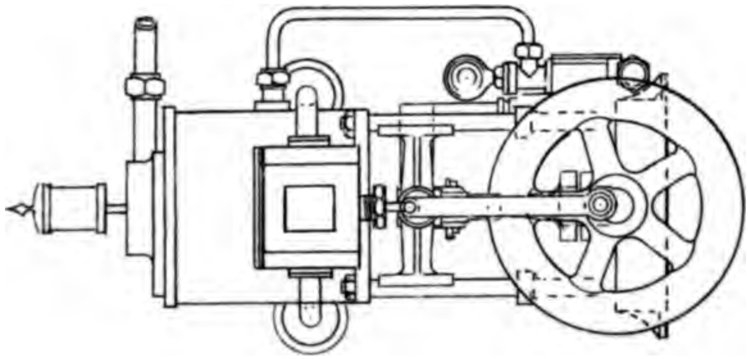


Fig. 2

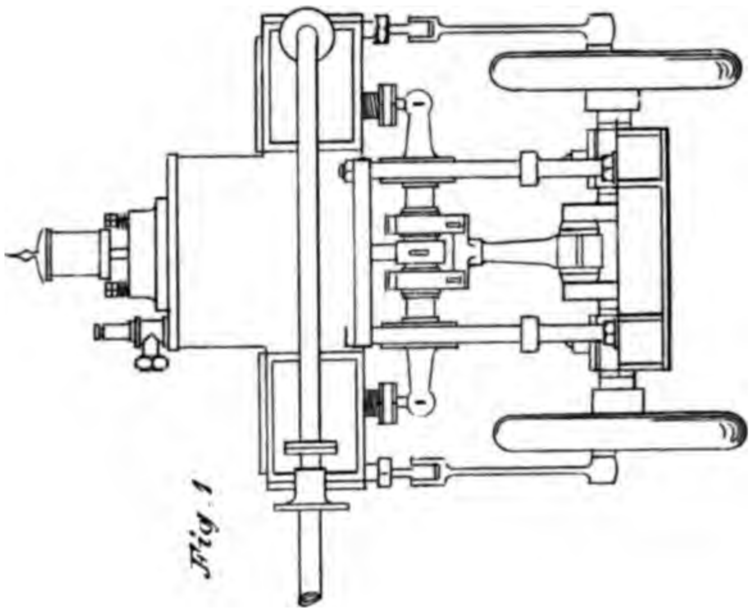
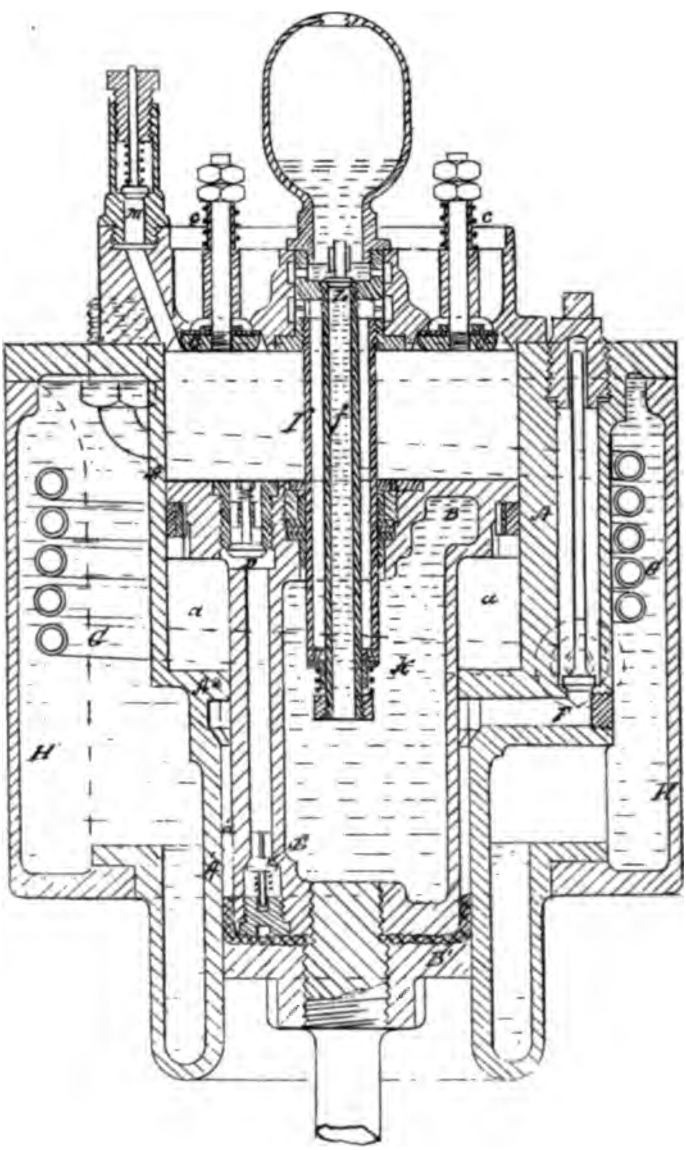


Fig. 1

BROTHERHOOD'S AIR COMPRESSOR.

..LXIII.



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are important adjuncts of the system, and require to be of special construction owing to the high pressure at which these reservoirs are charged.

At Pl. LXII. is shown a Brotherhood air compressor, Fig. 1 being an elevation, and Fig. 2 an end view of the same.

A vertical section of this compressing apparatus is represented at Pl. LXIII., the following description of which is taken from Mr. Brotherhood's patent.

The upper part *A* of the cylinder is fitted with a trunk piston *B*, connected to the piston *B′*, which works in the lower part *A′* of the cylinder; the two parts of the cylinder are separated by the ring *A″* through packing in which the trunk works. In the cylinder cover is fitted the annular suction valve *C* held up to its seating by springs *c*; in the piston *B* are passages fitted with valves *D* opening downwards, these passages communicating with the annular space *a* and other passages leading to the annular space *a′* fitted with valves E opening downwards. From the space *a′* a passage fitted with the discharge valve *F* communicates with the pipe coil *G*. The cylinder and coil are enclosed within a tank *H* containing water. To the cylinder cover are fixed the concentric tubes *I* and *J*, forming passages provided with the supply and discharge valves *K* and *L* for effecting circulation of water through the interior of the piston as above described; *M* is a relief valve. As the pistons descend air is drawn through the suction valve *C* into the upper part of the cylinder, and the air in the annular space *a* is forced through the valves *E* into the smaller annular space *a′*. As the piston ascends the air in the space above it is forced through the valves *D* into the annular space *a*, and the air in the annular space *a′* is discharged through the valve *F* and the coil *G* to the reservoir or other vessel provided for its reception. By the descent and the ascent of the piston water is drawn in through the valve *K* and discharged through the valve *L*, cooling the interior of the piston.

The piston may be worked by a crank or eccentric on a revolving shaft below, or by direct connection with the piston of a steam cylinder. It is of advantage to arrange several compressing pumps such as have been previously described to work from cranks on one shaft, these cranks being set so that the strokes of the several pumps succeed at equal intervals during each revolution.

Table XIV. compiled in 1886 affords data of the air compressors of Messrs. Whitehead, Schwartzkopff, and Brotherhood.

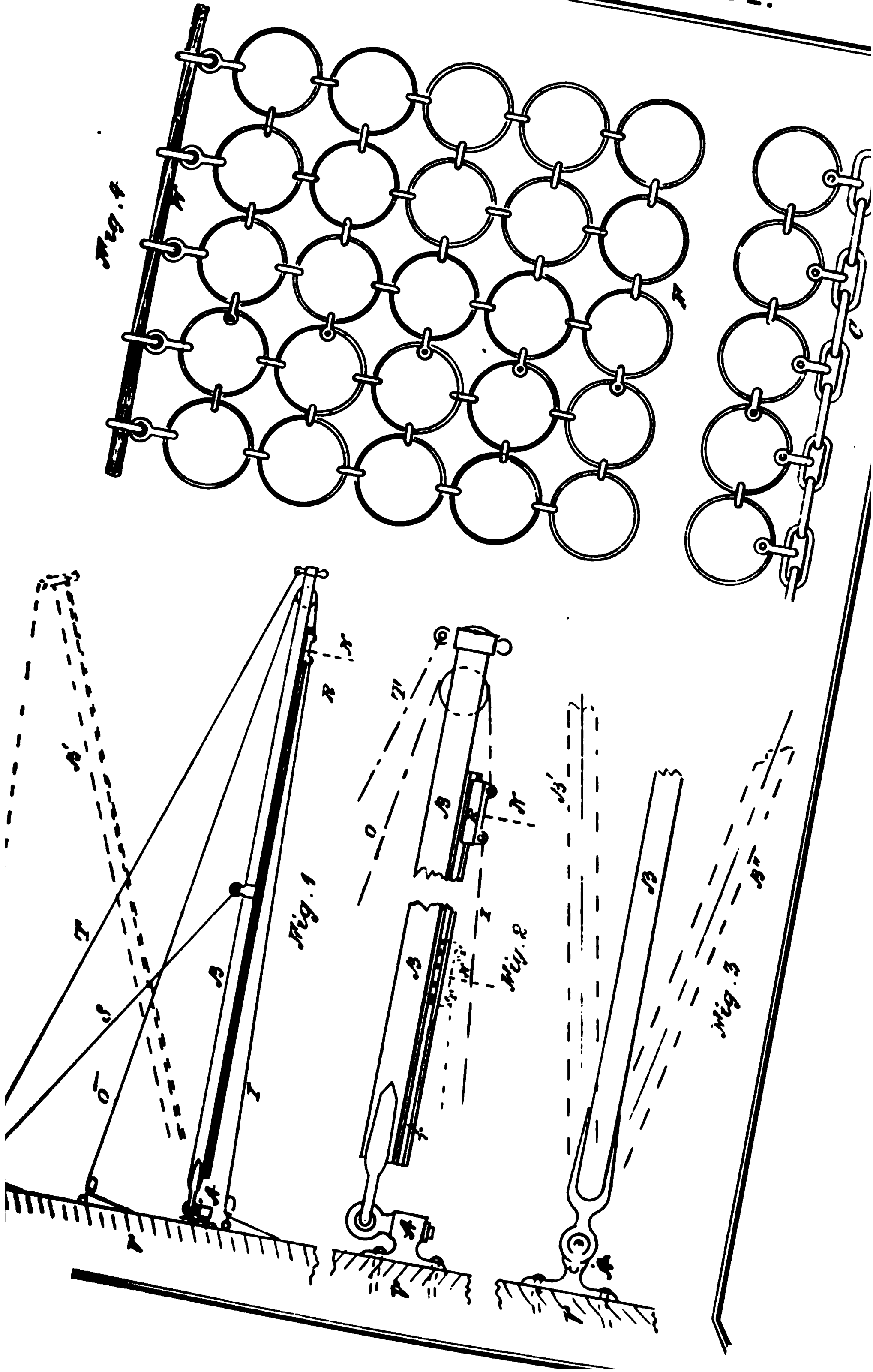
TABLE XIV.

System.	Weight.		Revs. per Minute.	Capacity to [illegible]		Remarks.
	Kgs.	Cwt.		Litres.	Cub. ft.	
Whitehead—Large .	[illegible]	42	[illegible]	700	24·7	Steam pressure 40 lbs. per sq. inch.
" Medium	[illegible]	15	155	400	14·0	" " 40 " "
" Small .	230	4½	250	120	4·25	" " 45 " "
Schwartzkopff—Large	430	8½	250	300	10·6	Steam pressure 35 lbs. per sq. inch.
" Small	100	2	450	100	3·3	" " 35 " "
Brotherhood—No. 3	2,300	46	240	1,130	40·0	Steam pressure 20 lbs. per sq. inch.
" " 10	900	18	350	933	33·0	" " 50 " "
" " 12	650	13	350	622	22·0	" " 50 " "
" " 11	250	5	350	311	11·0	" " 60 " "
" " 9	75	1½	450	100	3·3	" " 60 " "

The "Bullivant" Net Defence.—The protection of a man-of-war against its pigmy but deadly assailant the *Whitehead* torpedo is a matter of vital importance, but which, in so far as rendering a ship impervious to such an attack, whether at anchor or under weigh, remains yet a problem to be solved; judging from the recent experiments at Portsmouth with the *Resistance*, the Bullivant system of net defence appears to have satisfactorily demonstrated its effectiveness for forcing the explosion of a *Whitehead* at a safe distance from a vessel in a position where she is capable of using her nets without in any way detracting from her manœuvring powers, *i.e.*, when at anchor or moving at slow speed. Though this system may be readily put out, and taken in, and though the nets alone may be trailed up or lifted, by raising the outriggers clear of the water, yet it, or any other similar system could not well be used in an *action* at sea.

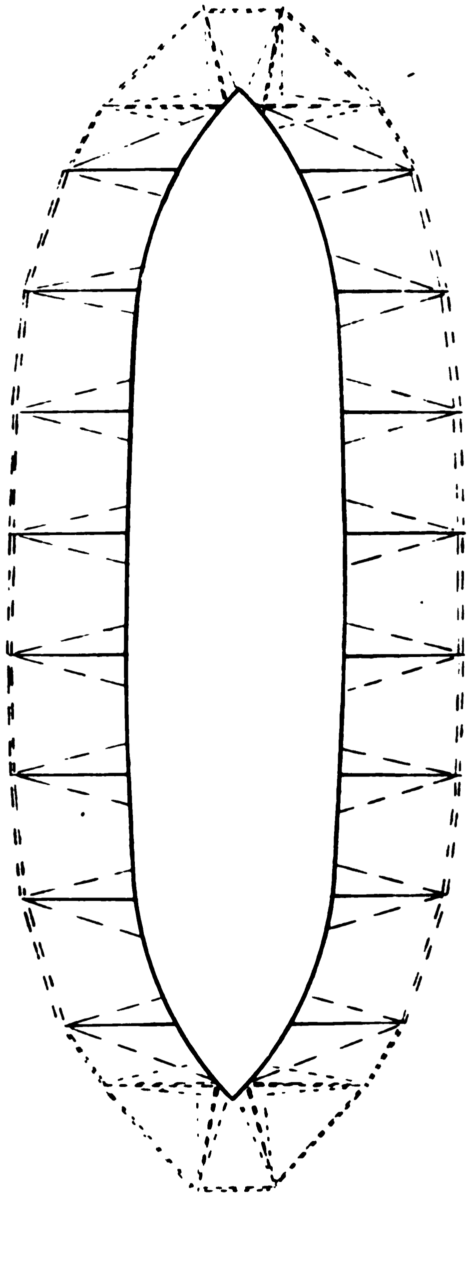
A ship's net defence requires not only to be capable of keeping a *Whitehead* from exploding in contact, or within the dangerous area of its charge, but must also be capable of being readily placed in position and taken in. Previous to the advent of the Bullivant *system* of net defence, a most cumbersome method of placing and maintaining the nets in position had been used, requiring some hours' work, while the wooden booms supporting the nets were very liable to be unshipped

PL. LXIV.



BULLIVANT'S NET DEFENCE.

.LXV.



either in heavy weather, or by a *Whitehead* exploding in the net, and were also liable to be broken from the latter cause.

By the adoption of hollow steel spars, weighing each 5 cwts. as against 10 cwts. for the old wooden booms; of a socket joint for the heel of the spar, instead of an ordinary hinge; of a runner, from which the nets are suspended, travelling in and out along guides under the spars, instead of fixing the nets permanently to the end of the wooden booms, Mr. Bullivant has succeeded in providing a most efficient and practical method of net protection for ships of war.

Pl. LXIV., Fig. 1, represents a side view of a Bullivant spar and its rigging, Fig. 2 being an enlarged view of the same; Fig. 3 is a plan of the spar, and Fig. 4 a view of the net.

B is the steel spar; *r* (Fig. 2) the guide along which the runner *R* travels; *T* is the topping lift; *S* the stay; *O* the outhaul; *I* the inhaul; *A* the socket joint; *V* the ship's side; and *N* the net.

The net attached to its runners may be run out and in by hauling on *O*, or *I*, or by merely lowering, and topping up the spars.

The socket joint enables the spar to be moved fore and aft as at *B'*, *B"*, Fig. 3, and to be topped up, or depressed.

In Fig. 4 *W* is the head rope of wire to which the upper grummets of the nets are attached by rings and clip hooks; the nets are usually made 30 ft. by 20 ft., and when two such nets meet they are joined together at the sides by means of shackles; *C* is the chain cable foot rope, also attached to the nets by shackles.

The nets are made up of rings or grummets of wire of 6 inches diameter, and are connected together by steel dies.

Pl. LXV. represents a plan of a ship provided with an all-round net defence on this system.

Remarks on the Defence of Ships against the Whitehead.—For ships forced to remain at anchor in any port accessible to the torpedo boats of an enemy, either by an accident to her engines or other causes, the net defence of Mr. Bullivant, supplemented by anchored boom obstructions at a distance, by guard boats, by electric lights, machine and other guns, would seem to offer a very fair means of beating off a *Whitehead* attack, as well as of preventing a *Whitehead*, should it be discharged, from exploding in contact with the ship. If the ship be anchored in a home naval port, there is no reason why more than one net should not be used, leaving some distance between them.

The object of the defence is to provide means whereby the approach and the position of hostile torpedo boats may be signalled as far off from the ship as possible; some such arrangement as lines of automatic signal light buoys connected together by wire, at known distances, would in a measure satisfy this condition. The costly first-class man-of-war of the present day is surely worth a considerable amount of trouble, time, and money to secure to it absolute safety from torpedoes when forced to remain at anchor, and more attention might be expected to be paid towards securing this desideratum than has hitherto been shown.

CHAPTER III.

UNCONTROLLED TORPEDOES (*continued*).

AUTO-MOBILE—"HOWELL"—"HALL"—"PECK"—"PAULSON" —MCEVOY.

1. The Howell Torpedo—General Remarks—2. General Description—3. Method of Propulsion—4. Method of Steering—5. The Method of Submersion—6. Methods of Launching—7. Original Official Trials—8. Further Trials—9. Improved Pattern—10. Characteristic Advantages—11. Other Types of Auto-mobile Torpedoes—12. The Hall Steam Torpedo—13. The Peck Steam Torpedo—14. Steam *v.* Compressed Air Propulsion—15. The Paulson Torpedo—16. Consideration of the modified Forms of Whitehead—17. McEvoy's Spring Torpedo.

GENERAL REMARKS.—The *Howell* auto-mobile fish torpedo was invented, in 1870, by Captain J. A. Howell, U.S.A., an officer of high mathematical attainments.

Although it has never yet been actually pitted against the "Whitehead," as it has so far been tried by the American Government only, the *one* Naval Power of any importance that has refrained from adopting the "Whitehead," yet from the published reports of the *Howell* experiments, in addition to more recent information received from the inventor, it seems likely to become a very formidable rival of that weapon; more particularly as the *Howell* possesses an *inherent* directive force, thereby remedying to a considerable extent the one grave defect of the "Whitehead" and kindred forms, viz., want of accuracy of direction.

The *Howell* torpedo, as at present perfected, has been the gradual development of the crude idea of a revolving spindle to which was attached an ordinary screw; the original idea being confined to surpassing the *spar* torpedo as to range, at the same time providing the weapon with a means of self-propulsion, and of maintaining its direction. The original United States patent of 1871 included a claim for the directive force of the fly wheel; but as this was not shown, only the claim for a new form of propulsion was allowed.

Description.—The following is a condensed description of the *Howell* from the most recent United States patent of 1885:—

The shell or case of the torpedo is made of thin metal, and is divided into five sections; it is shaped as shown in Pl. LXVI., where Fig. 1 is a side elevation, and Fig. 2 is a plan of this weapon.

The explosive charge is placed in sections *A* and *B*, the firing mechanism being in the former one; *C* contains the fly-wheel and gearing for driving the propellers: all these sections are water-tight. Between *D* and *E* is a water-tight bulkhead, in which are fixed the stuffing boxes for the propeller shafts. Section *E* contains the mechânism for operating the vertical (steering) *a a*, and horizontal (diving) *b* rudders; the fore part of this chamber is open to the water, and it is filled in with wood, so as to reduce the volume of water to a minimum.

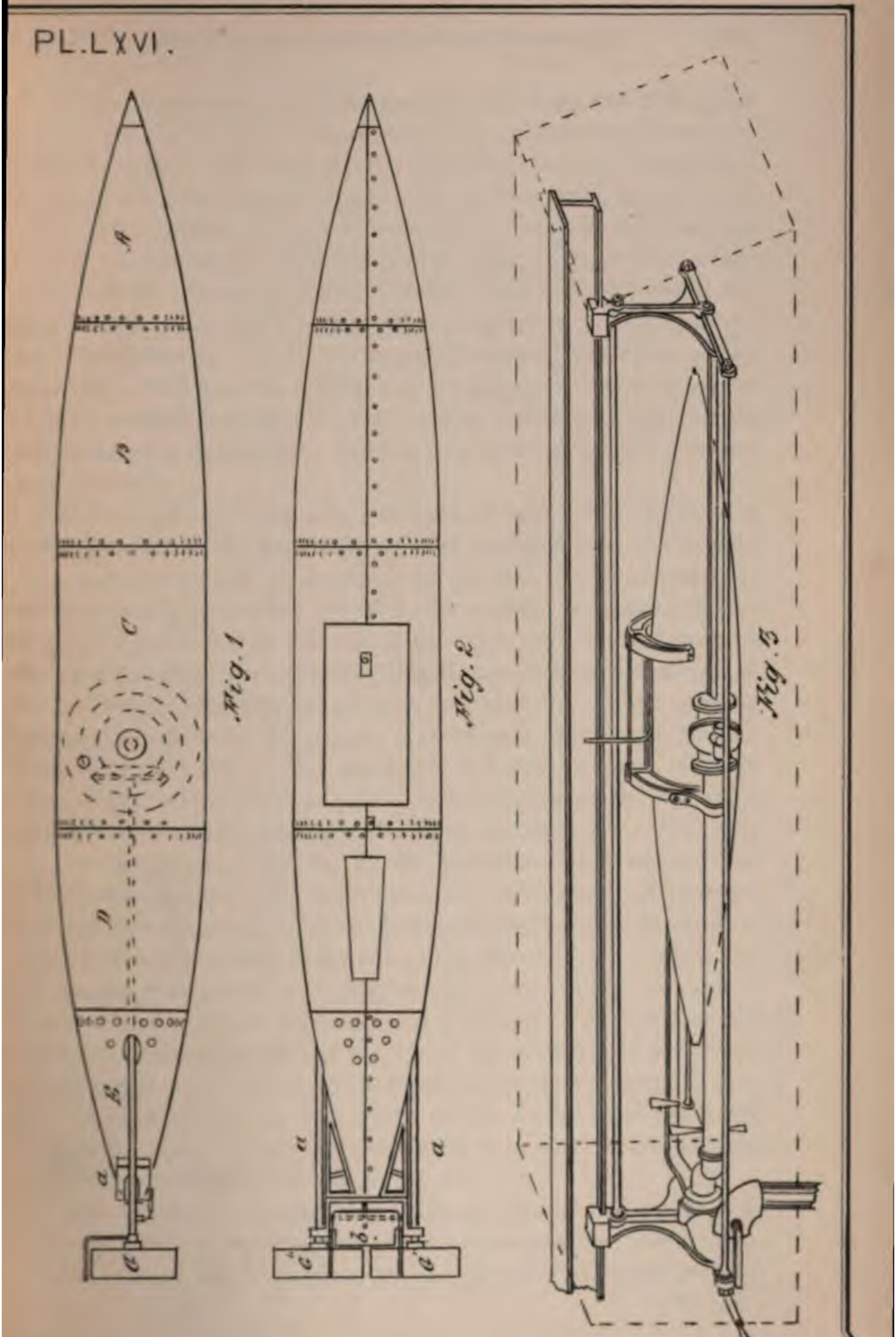
Method of Propulsion.—The torpedo is driven by two twin screws revolving in and protected by the tubes *G'*, *G''*; the propelling power is obtained from the revolution of a heavy fly-wheel at a high rate of speed transmitted to the propeller shafts by bevelled gearing. In Pl. LXVII., Fig. 1 is a vertical section, Fig. 2 a side elevation, and Fig. 3 a plan of the fly-wheel engine. *F* is the fly-wheel, the axis of which is at right angles to the longitudinal axis of the torpedo; *G'*, *G''*, the propeller shafts; *c*, *c*, bevelled wheels attached to the fly-wheel; and *d*, *d*, bevelled wheels attached to the shafts.

Method of lateral Steering.—The following description of the theory of the inherent directive force claimed for this torpedo is taken from the "Report of the Secretary of the United States Navy" for 1885:—

"The automatic steering apparatus is founded on the principle of component axes of rotation. The plane of the fly-wheel is vertical, and in the longitudinal axis of the torpedo; its axis of rotation lies in the horizontal plane. Now, when the fly-wheel has a high velocity, any force which tends to sheer the torpedo is resolved into a rolling motion about the longitudinal axis of the torpedo and a translation of the whole system (that is, the torpedo itself) in a direction perpendicular to the longitudinal axis of the torpedo; that is, the result of a deflecting force is to roll the torpedo and move it parallel to itself.

THE HOWELL TORPEDO.

PL. LXVI.



"When the torpedo experiences a deflecting force, and is in consequence rolled over to one side, the steering rudders are thrown into action in such a way as to exert a deflecting force in the opposite direction until the torpedo is again on an even keel, and the only effect on the torpedo is to move it bodily to the right or left of the course. If the torpedo originally headed south, it would head south during all the movements detailed above. This is the theory of the automatic steering which renders it unnecessary to make any allowance for deflection due to the torpedo's striking the water at any angle when fired from the broadside of a vessel under way at speed."

Two vertical rudders are used, turning on vertical axes in the framework, and arranged one on each side of the after portion of the rear section E.

These rudders are by arms and links or rods (which latter pass through tubes in the water-tight part of section E into the forward open part of said section) connected to opposite ends of a centrally-pivoted lever, whose axle is provided with a radial arm, connected by a link to a crank-arm on the axle of the tiller. By this arrangement both rudders can, by moving the tiller, be moved to starboard or port or be brought midships as occasion may require. The automatic action of the tiller for this purpose is as follows: On one of the propeller-shafts is a worm, which gears with and drives a wheel, mounted on a vertical axle in the open part of section E, and on the same axle is fixed another wheel, having a cam-rib on its upper face. The axle revolves continuously so long as the propeller-shaft revolves. The tiller overhangs the latter cam-wheel, and at its outer end carries a pivoted arm, arranged crosswise of the torpedo, the axle of which is hung in bearings on the under side of the outer end of the tiller, and is connected by means of a flexible shaft—for instance, a shaft of closely-coiled wire—to the axle of a pendulum. The axle of the pivoted arm is horizontal, and extends in the direction of the length of the torpedo, and the axis of the pendulum is on the prolongation of it. This arm at its ends has points, one or the other of which will engage the cam-wheel whenever the latter is inclined laterally in one direction or the other relatively to the arm.

The operation of the parts is as follows: The pendulum tends to keep the points of the arm always in a horizontal plane, and the cam-wheel normally lies in a plane parallel thereto. With the parts in this position the tiller is midships; but whenever by an extraneous deflecting force the torpedo is caused to roll upon its longitudinal axis in one direction or the other the cam-wheel is tilted or inclined in a corresponding direction with reference to the arm, which by its pendulum is maintained horizontal. Consequently the continuously-revolving cam-wheel is thrown into engagement with one or the other of the points of the arm, with the result of putting the helm to port or starboard, as the case may be, the flexible shaft permitting this movement. The steering rudders when thus moved set up a deflecting force opposed to the initial extraneous deflecting force, with the result of producing in the torpedo a tendency to roll in the opposite direction, the helm being put to starboard when the torpedo rolls to starboard, and *vice versâ*. This action will continue until the rudders have rolled the torpedo back far enough to permit the disengagement of the arm and cam-wheel, or, in other words, until the cam-wheel is in its normal horizontal position. In this way it will be seen that the torpedo can be automatically steered or kept from leaving the course in which it was pointed at the time it was launched. The rudders are not simply turned to starboard or port, as the case may be, and held there until the torpedo is brought back to its course. The revolving cam-wheel imparts to them a series of impulses, and this is kept up so long as the tilting arm engages the cam-wheel. The cam-rib may be so formed as to impart one or more impulses to the rudder or rudders for each revolution.

Method of Submersion.—The submersion of the torpedo is controlled by means of a horizontal rudder, which is operated automatically by mechanism, whose action is controlled by a combined pendulum and hydropneumatic cylinder, the piston of which moves with the varying external pressures at different depths. By a tilting arm and cam-wheel the action of this pendulum (which swings fore and aft) is transmitted in impulses, in much the same way as explained for lateral steering, the effect being to preserve horizontality of longitudinal axis; but the action is modified by the piston, which by its telescopic action in the cylinder changes the centre of gravity of the pendulum, causing it to turn in one direction or the other.

The tubes surrounding the propellers, by reason of the mass of water they contain, serve to steady the torpedo and to stiffen it against irregular movement in a vertical plane.

PL. LXVII.

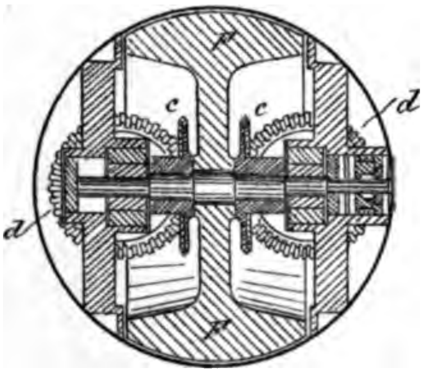


Fig. 1

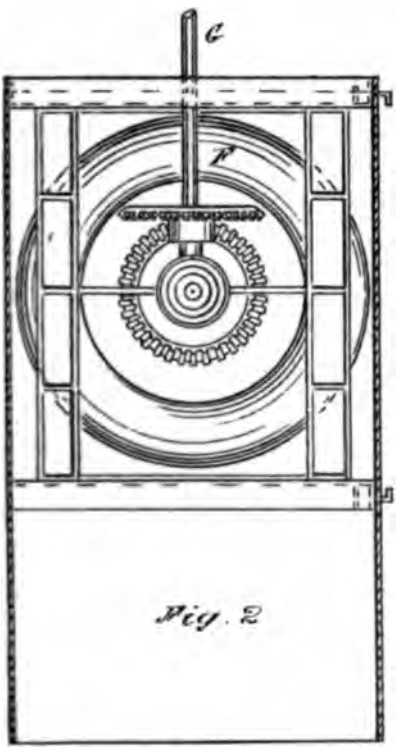


Fig. 2

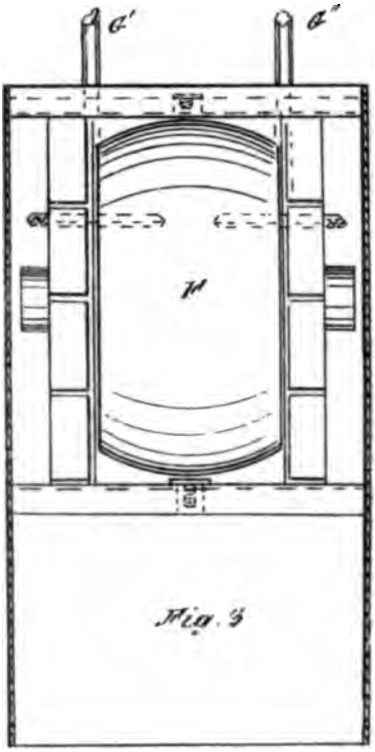


Fig. 3

Methods of Launching.—In the U.S. trials with the *Howell*, it was launched or dropped from the broadside by means of a frame or derrick extending from the ship's side, under which the torpedo was hung by clutches from studs on the shell. A modified form of this apparatus has been designed, as shown at Pl. LXVI., Fig. 3, to admit of its being enclosed in an armoured shield, and which also differs from the original form in that the torpedo itself balances the rocking frame in the place of a separate counter-balance weight.

The characteristic feature of this launching apparatus is that the portion of it which is connected to and supports the torpedo is free to move upon an axis at right angles to the position assumed by the axis of the fly-wheel when the torpedo is in place in the apparatus. The fly-wheel of course must be speeded up to the proper point before the torpedo is dropped or launched, and by permitting it freedom of motion about two axes at right angles to each other—the one its rotation axis and the other the axis of motion of that part of the launching apparatus in which the torpedo is hung or supported—it will not be injuriously affected by the motion of the vessel from which the torpedo is launched, and the strain which otherwise would come upon the fly-wheel and its bearings by reason of that motion is entirely removed.

The rocking frame which supports the torpedo is in this case hung on trunnions, and is counterbalanced by the weight of the torpedo. The steam for the Barker Mill (starting engine) is supplied through the trunnion.

Instead of using a crane to swing the torpedo outboard or inboard, the rocking frame is mounted in a frame hung from and arranged to slide on the stationary rail.

This arrangement is to be preferred to the original form, inasmuch as with it the apparatus may be readily shielded on top and at the sides and front by armour, as shown by the dotted lines. The torpedo may also be blown out of a tube, if this mode of launching be preferred or necessary.

Original Official Trials.—A series of experiments were carried out with a *Howell* torpedo by the U.S. Torpedo Board in May 1884, with the following results:—

Length of torpedo	8 feet.
Max. diameter	14 inches.

Weight of explosive charge	. 70 lbs.
Total weight	. 299 „
Weight of fly-wheel	. 108 „
Radius of gyration	. 5·4 inches.
Height of launching cradle above the water	4 to 7 feet.
Pressure of steam in the Barker's Mill .	. 40 lbs.
Duration of ditto ditto . .	40 to 70 seconds.
Initial speed for 100 feet . . .	8½ to 9½ knots.
Extreme range	. 500 yards.

Thirteen trials were made with this weapon, resulting in a satisfactory demonstration of its possessing an inherent power of direction, the Board reporting that "the horizontal accuracy due to the *directive force was* excellent with the *torpedo* when fired from the vessel at anchor or under way, and trained in various directions."

The Report then goes on to say that "the *directive force* inherent in this torpedo renders it unnecessary to make any allowance for the torpedo's being deflected on striking the water, even when fired abeam from a vessel moving at speed."

In speed and in uniformity of submergence this trial torpedo was found wanting.

Further Trials.—A newer type has, however, succeeded in attaining a speed of some 16 knots for 200 yards, and the following tabulated statement (p. 215) refers to certain trials carried out with this weapon in 1885, and is taken from the United States General Information Series, No. 5:—

"The torpedo tried was 8 feet 11 inches total length, 13·75 inches greatest diameter, weighed 284 pounds, had a buoyancy of 10 pounds in fresh water, and carried 40 pounds of lead to represent weight of explosive charge; the same torpedo in salt water would carry 60 pounds of charge without any buoyancy. It made a speed of 15·6 knots for 200 yards, and a total range of 500 yards with plane blades to the propeller."

Improved Pattern.—The following data refers to the recent improved type of *Howell* torpedo, and if only the figures relating to its speed and range be maintained in its official trials, combined with uniformity of submergence, it will certainly become the adopted torpedo of the United States, for naval purposes, as the United States naval authorities have been and are still searching for a torpedo of the "White-

TABLE XV.

No. of Trial.	Steam Pressure.	Time on Motor.	Range.	Rose at, feet from start.	Horizontal direction.	Remarks.
	Pounds.	Seconds.	Feet.			
1	50	20	1,200	No rise.	Straight.	
2	60	40	1,428	100	Ditto.	For about 200 feet could not see wake abreast station, indicating a constant depth.
3	65–62	40	600	Near start.	45 degrees to port.	Supposed to have struck bottom in 12 5 feet of water and was heading broad to port when it rose.
4	70	40	Lost.	100	Straight.	Could see wake for good part of run.
5	74–71	50	450	100–150	Ditto.	Found rear compartment partly adrift.
6	72–69	30	750	100	Ditto.	From station midway on course could see the Torpedo for 100 feet running 4 feet under water.
7	70	30	750	50–100	Ditto.	Ditto.
8	64–60	30	750	725	Ditto.	When it rose it was pointed to left, of course having run straight up to 725 feet. Only 11½ feet of water here.
9	65–62	30	100	..	..	Struck bottom 16 feet of water, and stuck till exhausted.
10	65	30	1,150	200	Ditto.	Same results as in 6 and 7.
11	70–66	40	Lost.	150–400	Ditto.	Speed about 13·34 knots.
12	78–70	60	400	100	35 feet to starboard in 400 feet.	Diving rudder pin broke before launching. Torpedo went to bottom and disconnected starboard propeller.
13	70	30	600	150	To starboard.	Did not drop fair, but pointed to starboard.
14	70	30	150	..	..	Struck bottom and stuck till exhausted
15	70	30	700	150	50 feet to starboard in 700 feet.	Did not drop fair, starboard stirrup held too long.
16	75	40	700	No rise.	Straight.	
17	62	40	850	No rise.	Ditto.	
18	70	40	890	200	Ditto.	
19	70	40	890	870	Slightly to starboard.	Did not drop fair.
20	77–71	60	1,598	350–1,300	Straight.	Speed 15·6 knots.
21	74–68	60	800	200	45 degrees to starboard.	Starboard propeller adrift.
22	70	15	600	No rise.	Straight.	
23	68–65	30	900	No rise.	Ditto.	
24	58	60	100	..	45 degrees to starboard.	Starboard propeller adrift and its blade and shaft sprung, propeller having fouled its inclosing cylinder.

head" type, but of home invention and manufacture; while on account of its inherent directive force, in other words great horizontal accuracy, it will unquestionably prove no mean rival in the immediate future to the celebrated "Whitehead."

Length of present *Howell* torpedo . . .	$8\frac{1}{2}$ feet.
Diameter	13^3 inches.
Total weight in air	325 lbs.
Weight of charge	70 lbs.
Displacement	331 lbs.
Guaranteed speed (1) for 200 yards . .	24 knots.
" " " (2) 400 " . . .	18 "
Total range for (1)	500 yards.
" " (2)	900 "
Weight of fly-wheel	110 lbs.
Radius of gyration	5·4 inches.

The power capable of being developed by the revolution of this fly-wheel depends on the velocity given to it, which is again dependent on the steam pressure in the Barker Mill starting engine, and duration of its application. With a pressure of 60 lbs. per square inch in the starting engine, maintained for *seventy* seconds, the fly-wheel has attained a speed of 160 revolutions per second.

Power developed is equal to $\frac{w}{2g} V^2 = 1\cdot72 \times (2\cdot83 \text{ ft.} \times 160)^2 =$ 352,647 foot pounds.

With a pressure of 90 lbs. for *thirty-three* seconds, the fly-wheel attained a velocity of 115 revolutions per second.

With a pressure of 65 lbs. for *forty* seconds, the power developed in the fly-wheel has been sufficient to turn the propellers of the torpedo in air for *forty* minutes. The fly-wheel has an elastic limit of 30,000 lbs., and tensile strength of 80,000 lbs. per square inch; to strain it to its elastic limit requires 240 revolutions per second.

Characteristic Advantages.—The *Howell* small torpedo possesses the following characteristic advantages:—

1. Small size, handiness.
2. Simplicity, cheapness.
3. Large explosive charge for size, 1 lb. of explosive to $4\frac{1}{2}$ lbs. of total weight.

4. Absolute directive force, great horizontal accuracy.

5. Perfect reliability when fired from the broadside of a ship in motion.

6. Armour protection to the launching apparatus.

As compared with the "Whitehead," this torpedo is superior in all these particulars, but it is inferior to the former in the matter of speed, and it has yet to prove a similar reliability in the matter of uniformity of submergence and effectiveness in application.

An objectional feature.—The necessity of using in the *Howell* an external source of power for developing its propelling force and which must be applied up to the very moment of launching it, constitutes a defect in the system, as compared with the "Whitehead," and this may always be considered as a very serious objection by those inimical to its employment.

If however, at a range of say 500 yards, the *Howell* torpedo as pitted against the "Whitehead" proves the possession of greater accuracy due to its inherent "directive force," it can very well afford to admit its inferiority in the matter of speed, and of facility of launching, as its superiority in regard to certainty of hitting would more than balance its inferiority in these respects; for "certainty of hitting" is the leading essential of every torpedo, more especially of the *uncontrollable* type.

Other types of Auto-mobile Torpedoes.—The fact of Mr. Whitehead having made the construction of his torpedo a secret, instead of the subject of a patent, has been the cause of the many attempts that have been, and are being made to devise a similar but superior weapon, either in regard to higher speed, greater accuracy, increased uniformity of submergence, or in some other quality, as though such a procedure has been accepted as a challenge to all comers, first, to discover the *modus operandi* of the secret parts, and then to construct a weapon equal to or surpassing the "Whitehead."

Up to the present time this metaphorical challenge, though taken up by many scientists and inventors, has not been productive of a fish torpedo which is now capable of equalling the "Whitehead" in all its many excellent qualities, though with the *Howell* (already described), Hall, Peck, and Paulson patterns actually in the field, the day may be approaching when the prototype of this class of torpedo will be ousted from its high position by a more excellent and more favoured type of fish torpedo, in which is combined some one or other of the more advantageous features of the foregoing patterns.

The "Hall" Steam-torpedo.—The description of this weapon is taken from Lieutenant Seaton Schroeder's U.S.N. account of torpedoes in the General Information Series, No. VI., U.S.

The fish torpedo, designed by Lieutenant Hall, U.S. Navy, has the shape of a spindle of revolution, carrying the charge in the nose, with a percussion apparatus.

The motive power is steam, which, together with a suitable quantity of water heated to about 550°, is stored in a flask or generator. As the pressure is reduced by the consumption of the steam, the heated water gradually vaporises, furnishing a continual supply. The engine drives twin two-bladed screws whose disk areas overlap, they being so placed that when the blades of one are vertical those of the other are horizontal; a simple gearing compels the two shafts to make the same number of revolutions, thus preventing any possibility of the blades interfering. By this means a large disk area is obtained.

The other special features in this torpedo are in the apparatus for regulating the submersion, no assistance being derived from the hydrostatic pressure. When ready for use, the torpedo has a buoyancy of 15 to 30 pounds. To cause it to maintain a practically horizontal path under water, a pair of diving fins is fixed on the nose, inclined downward to an extent found sufficient to counteract the buoyancy, the depression of the nose being checked by a drag made fast to the tail, which by pulling back on it has a tendency to bring the stern down to a level with the bow. As the steam and water are used, the buoyancy increases, and the angle of the diving-fins has to be increased proportionately. This is done in the following manner: within the shell of the torpedo, on each side, is a fore and aft cylinder containing a piston, one side of which is pressed by a spiral spring, and the other by steam or water from the flask. A piston rod goes forward to abreast the diving-fin, with which it is connected by a shaft through the shell and a system of racks and pinions; with the fins in their normal position, the steam pressure and that of the springs counterbalance each other in the cylinders; but as the water is used (increasing the buoyancy) its pressure decreases, and the springs prevail over it, and, pushing the pistons and rods, alter the position of the fins. In order that the fins should work efficiently it is necessary that the speed of the torpedo should be regular, and to that end a governor is placed on a prolongation of the shaft. This governor, while simple in principle, is extremely sensitive, and moreover can be regulated to control the speed to within twenty revolutions. In fact, uniformity of speed is depended upon, in place of hydrostatic pressure, to regulate the submersion.

It is evident that any rolling of the torpedo would cause the diving fins to act with a lateral component; to prevent this, lateral righting fins are provided just abaft the diving-fins and below the horizontal plane of the axis of the torpedo. They are hinged at their forward end, and normally lie close in against the hull, being pushed out, when needed, by the righting engines, as follows: A double bent U tube, in a vertical thwartship plane, contains mercury; each vertical arm contains a valve chest floating on the mercury column; connected with each valve chest is a horizontal thwartship cylinder fitted with a piston and rod, which latter, passing though the shell of the torpedo, takes against the righting fin. When the torpedo rolls to either side the mercury rises on that side, pushing the valve up and opening the port leading from the flask to the cylinder, and the piston rod and fin are forced outward; the surface of the fin, being exposed to the upward pressure of the water outside and beneath the torpedo, causes it to roll back to an upright position, on attaining which the mercury falls in that branch of the pipe and closes the valve, and the fin is pushed back in place by the water pressure.

The *Hall* torpedo is still in the experimental stage. In the few trials carried on so far, it has been found to possess good and regular speed, and the lateral steering apparatus worked satisfactorily.

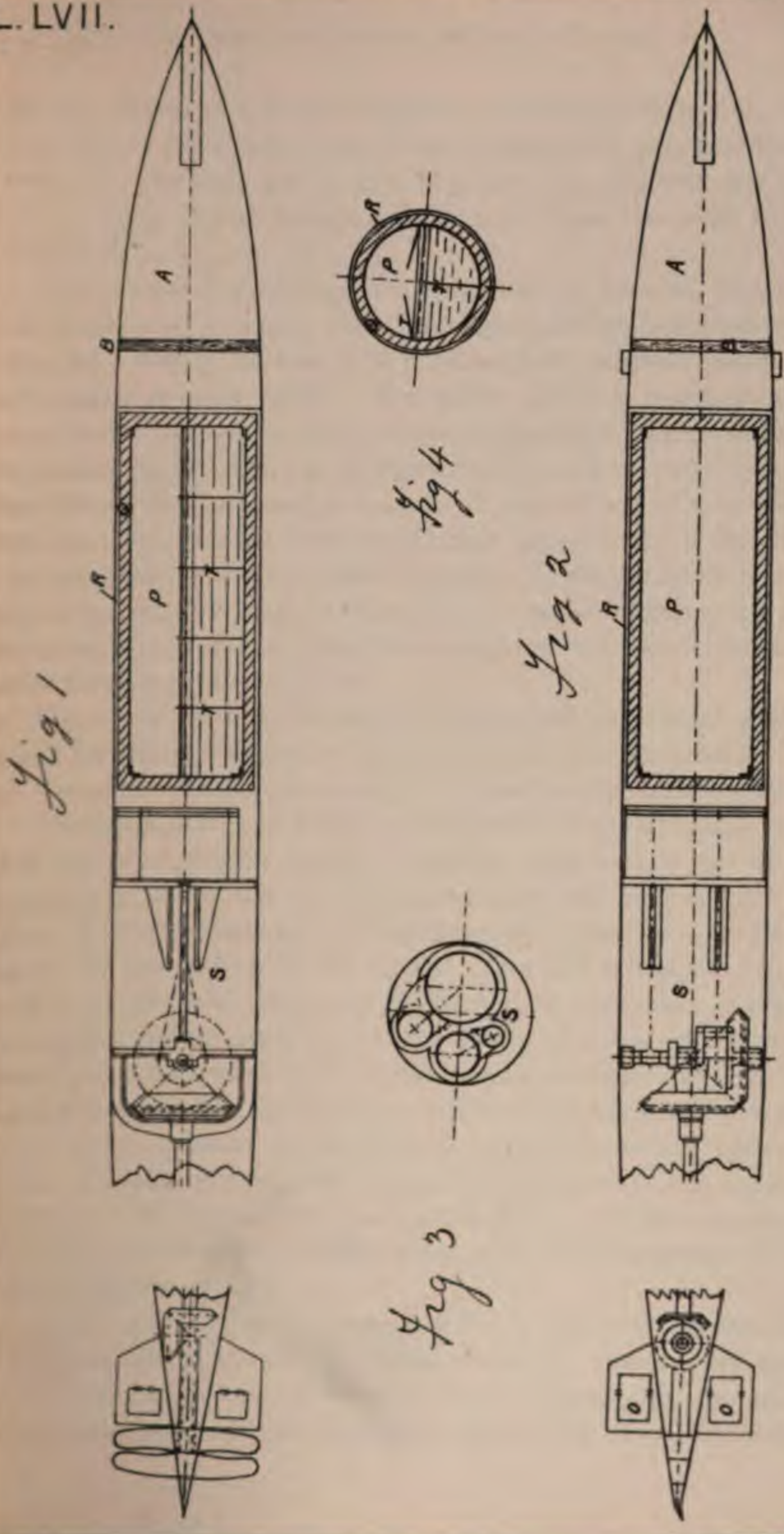
The "Peck" Steam Torpedo.—Mr. Edward C. Peck, who has charge of the draughting department at Yarrow and Co.'s Torpedo Boat Works, has designed a fish torpedo to be propelled by steam. It is of the usual "Whitehead" pattern outside, being 14 ft. long, by 14 in. diameter, and it will carry 100 lbs. of gun-cotton. This torpedo is shown at Pl. LVII., where Fig. 1 is a sectional elevation, and Fig. 2 a plan, Figs. 3 and 4 being cross sections. At about the centre is a hot water reservoir, *P*, 4 ft. long and 11½ in. internal diameter. This reservoir will be surrounded by a coating of non-conducting material ¾ in. thick, and between the outside and this and the skin of the torpedo will be an annular space, *R*, of ⅜ inch. The reservoir is to be charged with about 160 lb. of hot water taken from the main boiler of the torpedo boat, and is provided with a safety-valve. The water, which only partially fills the reservoir, will be transferred very rapidly at a pressure of about 400 lbs. per square inch, and there will be means for raising the temperature of the water, if necessary, during its transfer from the boiler of the boat to the reservoir of the torpedo. It is calculated that the torpedo will keep steam for at least an hour after it has been charged. The quantity of water carried will possess sufficient sensible heat to supply the propelling engines with steam of a slowly decreasing pressure during the run of the torpedo. The space between the reservoir and the skin of the torpedo, as also a portion of the space in the body of the torpedo, not otherwise occupied, is utilized as a surface condenser. By this means the weight of the torpedo will be precisely the same at the close as at the commencement of the run. *T*, *T*, are partitions to prevent the washing about of the water in the reservoir; *A* is the charge compartment, and *B* a block of wood used as a non-conductor of the heat in *R*. The torpedo will be fitted with engines of 60 horse-power indicated, and capable of propelling it through the water at a speed of 32 knots an hour. It will be fitted with the usual fins, rudders, and regulating apparatus to insure its travelling at any required depth and in any desired direction.

Steam v. *Compressed Air Propulsion.*—Steam propulsion for fish torpedoes, as compared with compressed air, has certain advantages *claimed* for it. In the first place, weight is saved in the torpedo, and, as a comparatively low pressure of steam is used, the trouble experienced in keeping joints and connections tight is removed; while the length of full power run with, and speed of, a steam-propelled torpedo, as compared to the *Whitehead*, is *claimed* to be as 1·75 mins., or 1800 yards, to 0·75 min., or 600 yards, and as 32 knots to 24 knots respectively.

As regards the question of increased range, it does not seem that there is any special advantage gained, unless with the power of increased range there also be provided a corresponding power of increasing the lateral accuracy of the torpedo in the same degree. It is also very possible that as soon as a *steam Whitehead* is produced of 30-knot speed, a similar or greater speed will have been realised with the compressed-air Whitehead.

The disadvantages of steam propulsion are mainly in connection

L. LVII.



with the important feature of facility of handling the torpedo, but until definite experiments have been carried out, it is impossible to foresee the *disadvantages* (if any) of a new type, differing radically from existing types, though all its advantages are well known beforehand.

The "Paulson" Torpedo.—This pattern differs from the foregoing, first, in regard to its motive power, which is liquid compressed carbonic acid, and secondly, in that it is provided with *automatic* means for maintaining a given course. The motive power is stored under a pressure of 1500 pounds, which is released gradually, and, volatilising, passes through the nozzle of an injector surrounded by water from the sea; the gas thus produced is made to act upon a body of water taken into the vessel through suitable openings, and discharged therefrom through nozzles on the well-known principle of the injector or ejector. Water thus acted on may, by its reaction, be applied direct to the propelling of the torpedo, or it may be arranged to act upon a turbine or water-wheel to work a propeller.

The lateral steering is effected automatically by means of electricity brought into action by the movement of a compass needle.

A mariner's compass is placed in the head, or other suitable part of the vessel, the needle of which is connected to a powerful battery, or other source of electric energy. Upon the same axis as that of the needle is placed a dial of non-magnetic material marked with the points of the compass, and capable of movement upon its axis without disturbing the position of the needle. This dial carries two copper, brass, or silver studs, electrically insulated from each other, and from the needle. Each of these studs is electrically connected with the coils of an electro-magnet, so that when the needle touches either stud, the soft iron core of the coils connected with that stud becomes a powerful magnet, and capable of exerting force in a certain direction; while the other, if similarly connected, attracts an armature in the opposite direction; one only acting at any given time; and thus capable of moving the tiller of the rudder directly, or by the intervention of any convenient form of power.

Before launching the torpedo, the dial is set to the bearings of the object aimed at, and the studs, which are conveniently made removable, are set upon the dial in such a manner that the needle points between them when steering direct for the object, but should any slight deviation occur, immediate contact with one of the studs takes place, the rudder is moved so as to bring the vessel again upon her course, when the contact is broken, and the rudder is brought back to its normal position by spring, or other suitable pressure.

The inventor of this weapon suggests in his patent, and in a lecture delivered at the R.U.S. Institution, March 26th, 1886, various applications of this principle by the aid of which the torpedo could be made to perform a variety of other automatic operations; but though they are feasible, yet they necessarily introduce further complications in an already sufficiently complex machine.

A description of an electrical apparatus, devised by Gunner Burdett, for steering a fish torpedo, which is practically similar in principle to the *Paulson* method, is contained in the Appendix to Lieutenant F. M. Barber's U.S.N. lecture on the Whitehead torpedo, 1874. This idea was intended to be used with the fish torpedo designed by the U.S. torpedo officers, but it does not seem to have met with any favour.

Consideration of the modified Forms of Whitehead.—The Howell, Hall, Peck, and Paulson, modification of the *Whitehead* torpedo present features of more or less practical value and interest; the "Howell" in the possession of an inherent directive force; the "Hall" and "Peck" in the employment of a motive power (steam) in every-day use, and with which a speed higher than at present attained with the *Whitehead* is anticipated; and the "Paulson," in the use of a special motive power, which is also expected to realise very high speeds, and in the possession of an automatic lateral steering apparatus.

With the exception of the "Howell," which possesses a distinct advantage in respect of its peculiar motive power that produces an inherent directive force, the other three patterns do not seem in the present stage of their existence to offer sufficient advantages for their adoption in the place of the present form of fish torpedo; while even the "Howell" has certain objectionable features in regard to the application of its motive power, though possibly these will not be found in actual practice to outweigh the *important* advantage of *increased accuracy*, and consequently greater certainty of hitting. If an *uncontrollable* auto-mobile torpedo be retained as the torpedo armament of ships and boats, then the "Whitehead" (in which is included the Schwartzkopff) is unquestionably the most perfect pattern extant, and any other one which realizes in a higher degree the perfection attained by that weapon in regard to speed, uniformity of submergence, accuracy of direction, range, facility of handling, adaptability for ship and boat use, and simplicity, will indeed be a wonderful creation.

McEvoy's Spring Torpedo.—This invention hardly comes under the category of auto-mobile fish torpedoes, in so far as the "Whitehead" represents this class, because though it is shaped like a fish, yet it is provided with a means of propulsion only, no arrangements being made for attaining an uniformity of submergence, as it is only intended to utilize it for very short ranges.

The object of Capt. McEvoy's invention is actually to afford as it were to the *spar* torpedo a means of striking at a distance very considerably beyond what is possible with that weapon as ordinarily used, and he arranges for this by fitting to the end of the spar a small fish torpedo propelled by coiled springs, after being discharged by means of a powerful spring from a tube or holder at the outer submerged end of the spar. This form of attack, while doing away with the necessity of the torpedo-boat running almost into contact with the ship to be attacked, retains all the effectiveness as to certainty of hitting of the ordinary *spar* torpedo.

CHAPTER IV.

CONTROLLABLE TORPEDOES.

SPAR—"McEVOY"—"BERDAN"—TOWING—DIRIGIBLE—"BERDAN."

DEFINITION.—This division includes all those torpedoes which remain under the absolute *control* of the operator during the whole length of their run, or, in other words, those which are in mechanical or electrical connection with the station from which they are operated from the time of being started on their course to the realisation of their attack.

Classification considered.—In the list of types of *controllable* torpedoes enumerated at page 159, Division II., the spar, locomotive, and auto-mobile types satisfy the above definition in the most absolute manner, as they are *controllable* in every respect; they can be started and stopped at any time, steered to port or starboard, and fired either by contact or at will.

The *divergent towing* torpedo, Class B, fails, to some extent, in regard to directive control, but satisfies the other requirements; while the *dirigible* torpedo, Class C, only fulfils the requirements of controllability in the matter of lateral direction.

These two classes, notwithstanding a certain want of absolute control, fairly belong to the group of *controllable* torpedoes, for they arecertainly not uncontrollable, but they have usually, together with the spar, been treated as being a separate division of torpedoes.

Controllable v. *Uncontrollable Torpedoes.*—There are two distinct functions of warfare in which the torpedo has an important part, viz., as the armament of ships, and boats for purely naval engagements, and as forming part of the submarine defence of harbours.

As a naval weapon, the best type of *uncontrollable* torpedo, the "Whitehead," is superior to each of the types of *controllable* torpedoes enumerated in Division II. in the following particulars:—

The "Spar," in regard to range; the "Divergent towing," in the matter of range and facility of handling; the "Dirigible," in the matter of facility of handling, and certainty of action; the "Locomotive" and "Auto-mobile" in respect of facility of handling *only*.

As a weapon for harbour defence, i.e. one which can be manipulated from the shore, the "Whitehead"[1] is altogether inferior to the "Locomotive" and "Auto-mobile" (controllable) types; the "Spar" and "Towing" cannot be used as such, but the "Whitehead," though essentially a ship torpedo, can be utilised for harbour defence by means of submerged forts.

The superiority of the "Whitehead" over the "Auto-mobile" type of *controllable* torpedoes, for *naval* purposes, is a matter of opinion, and will be more particularly discussed when Class E comes to be considered.

A.—Spar Torpedoes.

The *Spar*, or as it is sometimes termed the "Pole" or "Out-rigger" torpedo is the simplest form of a submarine offensive weapon extant; while, as it is carried to the point of attack in a *manned* boat or ship, it must be considered as possessing the feature of *controllability* in the most absolute manner.

Defect.—It has, however, one insuperable defect in that it has practically no range of attack, and therefore in these days of machine and quick-firing guns, electric lights, and nets, the *Spar* attack can be readily repulsed by a ship duly prepared to meet it.

Employment in the American Civil War.—This torpedo was brought prominently into notice by its successful application during the American Civil War, when the power of ship defence compared with what is possible in that direction at this time was proportionately very much smaller than the comparative capabilities for attack then and now. Since that war the power of ship defence has developed far more rapidly than the means of attack by the *Spar*, thus causing a demand for a submarine weapon possessing the power of delivering its blow at a distance from the operating point. The demand thus created was for a time satisfied by the "Towing" torpedo, which weapon has since been discarded for the "Auto-mobile Fish" torpedo; and the rapid development of this latter type, represented by the "Whitehead," was very nearly causing the "Spar" to share the fate of the "Towing" torpedo.

French Successes.—The *Spar* would have probably been, before this time, expunged from the list of naval weapons but for the successful issue of its employment by the French in Chinese waters in 1884.

Value Under Special Circumstances.—These French successes with their *Spar* torpedoes unquestionably prove that, under certain given conditions, this weapon is most effective and most deadly; as for instance, for the attack of a ship at anchor, unprovided with any kind of external protection, such as nets, or booms, and where by the absence of a proper look-out, the torpedo boat is enabled to get *close* up to the vessel *before* being observed.

Only Successful Torpedoes.—All the ships that have so far been injured or sunk by torpedoes have met their fate at the hands of the *Spar* torpedo, with the exception of one extremely doubtful case, of a vessel sunk by a "Whitehead" in the Russo-Turkish war of 1877, and this fact alone would seem a sufficient warranty for its retention, if only as an auxiliary weapon of submarine offence for use under certain circumstances.

Further Uses.—For clearing away booms, and such like obstructions placed across a harbour or river mouth, the *Spar* torpedo will be found most useful; while it has the advantage of being cheap, simple, and readily adapted to any ordinary service boat.

Improvements.—Since its first conception, the *Spar* torpedo has received considerable attention with a view to simplify its fittings, to increase its effectiveness, and to insure an absolute certainty in its action.

The introduction of the higher explosives, dynamite and gun-cotton in the place of gunpowder, the use of steel instead of wooden spars, the adoption of electrical ignition in the place of mechanical, and the development of the fast steam torpedo boat, and electrical marine

THE McEVOY SPAR TORPEDO.

PL. LXVIII.

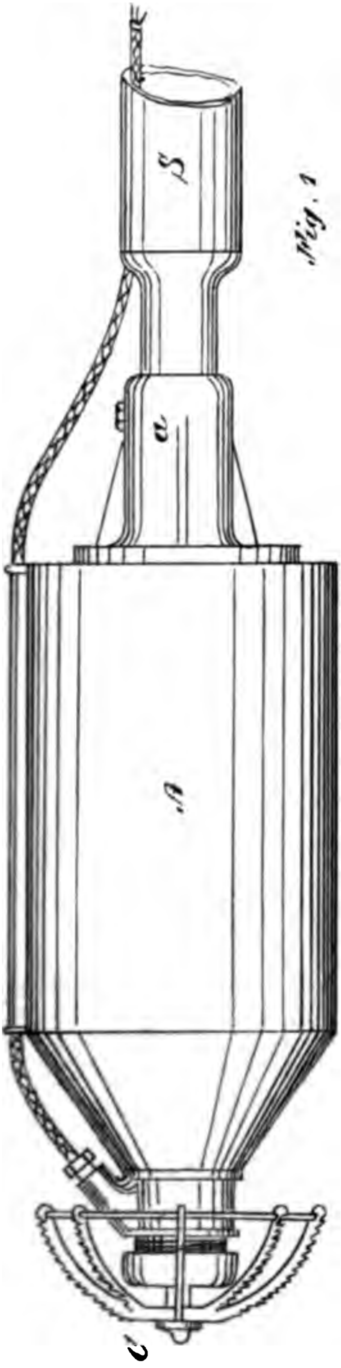


Fig. 1

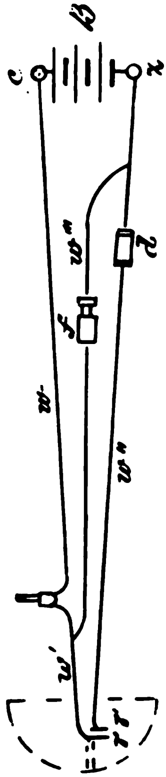


Fig. 2

Fig. 3

propulsion, have together combined to very greatly enhance the value of the *Spar* torpedo as a weapon of offence in the present day.

Description of the McEvoy Type.—The "McEvoy" form of *Spar* torpedo, shown at Pl. LXVIII., is the one most generally used, and is so well known that it will be only necessary to give a brief description of it. The case *A* containing the charge of explosive is provided with a socket *a* in its base, in which the hollow steel spar *S* is fixed. The amount of the charge varies from 100 lbs. downwards, depending upon the class of boat it is to be fitted to. At Fig. 2 is shown a plan of the connections, which are as follows: One pole *c* of the battery *B* to one terminal of the fuze by the wire *w*; the other fuze terminal by the wire w^1 to the contact piece *r*; the other contact *r'* by the wire *w''* to the other pole *z* of the battery, and in this wire is inserted the contact breaker *d*; a branch circuit is formed by the wire *w'''*, in which is placed the firing key *f*. At Fig. 3 is shown an enlarged section of this firing key; the contact breaker is similar to this key, with the exception of their being no spring, contact being made or broken in this case by screwing together, or unscrewing the two parts; by means of a safety wedge the key *f* may be prevented from acting.

With the contact breaker unscrewed, and the safety wedge inserted in the firing key, the fuze circuit cannot be closed either by "contact," or "at will"; with *d* closed, "contact" firing only can be used; with *d* open, and the safety wedge removed from *f*, "at will" firing only is possible; with *d* closed, and the safety wedge of *f* removed, either kind of firing is possible. To insure the action of the "contact" firing apparatus when the blow is not direct, a rocking cradle *C* is fitted. A hollow spar is used to protect the cable containing the three insulated wires.

In attacking a ship, firing "at will" would not be necessary, and if used might lead to the premature explosion of the torpedo in the excitement of the final rush under fire; it would, however, be very useful in destroying booms, as for such operations it might be required to place the torpedo underneath the boom, and fire it deliberately.

General Remarks.—When fitted to boats, the *Spar* is now generally arranged to be rigged out a-head, and the necessary submersion of the torpedo is obtained by raising the heel, the pivot being fixed; if used in ships the spars would be rigged out on each beam and fitted in a similar manner to the lower booms of a ship. The beam rig for boats, which is simply a tactical consideration, has not found much favour amongst naval men; while the Federal scheme of a dropping magazine, reintroduced by Weeks' patent of 1883, attacks the very essence of the effectiveness of the *Spar* torpedo, viz. its simplicity.

The Berdan Type.—Another form of *Spar* torpedo attack, devised by Capt. McEvoy, has been explained at page 223, Chap. III., by which the great defect of the true form of *Spar*, *want of range*, will be to some extent overcome; and with a similar object in view General Berdan has devised a form of torpedo attack which, strictly speaking, is not a *spar*, yet has all the features common to that weapon, with the addition of being capable of circumventing a ship's net defence.

The "Berdan" system is as follows: about 50 feet abaft the bow of the torpedo boat, a strong tube or light cannon is fixed vertically and opened downwards, one on each side; in each of these tubes a torpedo (8 feet by 14 inches) is placed, and connected by a wire to a stout bumpkin placed forward on each bow. The torpedo is propelled by means of four (6-inch) rocket tubes, each 32 inches long, and carries a 200-lb. charge of explosive.

A long pole projects ahead of the boat, which on striking the enemy, reverses the boat's engines, and fires the rockets; the gas, thus generated by the rockets in the tubes, ejects the torpedoes downwards, swinging them forward round the bumpkins as centres by the wire, thus causing them to pass under the net into contact with the ship.

B. Towing Torpedoes.

Definition.—By a *towing* torpedo is meant a charge of explosive contained in a case of special form, arranged to be diverged from the side of a vessel when towed.

In the present form it can be fired electrically by "contact," or "at will," and is controllable in that it is always mechanically connected by towing lines to the vessel from which it is operated.

Historical.—This species of torpedo is said to have been suggested as far back as 1815, and it had been intended to use it in an attack on the U. S. steamer *Housatonic* in 1864, but it was reserved for Captain J. L. Harvey, R.N., to bring it into practical use in 1869; and this class of torpedo is now usually known by his name.

The "Harvey" was, in the first instance, adopted by Russia in 1869, then by England (1870), and afterwards by many other countries.

Special forms.—In France, Germany, and the United States special kinds of *towing* torpedoes were devised, differing somewhat from the original "Harvey," as adopted by Russia, England, and other countries.

Cause of its being discarded.—The exceeding skill and judgment necessary to successfully operate this torpedo, its comparatively short range (only some 70 to 100 yards), and the rapid development of the "Whitehead," tended to gradually bring this weapon into disfavour; the final blow being given by its failure in the hands of the Russians in 1877.

The French were the last to retain it, but in 1886 they finally discarded it in favour of the "Whitehead."

Description of any type unnecessary.—As the *towing* torpedo has for the present fallen into complete disuse, and as all the principal types are well known, it will be unnecessary to enter into a description of any of them.

C. DIRIGIBLE TORPEDOES.

Definition.—By *dirigible* torpedoes are meant those which are controllable only in respect of their lateral direction.

The "Callender" torpedo, patented in 1862, is one of the earliest known attempts in this direction; this weapon was propelled by rockets, and was steered by means of light lines leading from the rudder yoke to the point of manipulation. The "Callender" system has been revived within the last few years in the "Berdan" torpedo; and still more recently the "Nealy" *dirigible* torpedo has been patented.

Description of the Berdan Type.—The "Berdan" system of *dirigible* torpedo will be briefly described here, though it has not yet proved its practical efficiency, on account of the novelty of the special means devised for overcoming the obstruction afforded by a ship's torpedo nets.

In Pl. LXIX. a sectional elevation at Fig. 1, and plan at Fig. 2, of this torpedo is shown. Pl. LXX. illustrates the mode of using the system, which requires two torpedoes, one towed by the other. The leading one is slightly more powerful than the other, and is dirigible, being steered from the shore or a ship.

The torpedo shown in Pl. LXIX. is 31 feet long, 21 inches wide, 31 inches deep, and weighs 1¼ tons.

The explosive charge is 220 lbs. of dynamite, ignited by percussion.

The motive power consists of 12 (6-inch) rockets *R*, in three rows of four each; the gas generated by these rockets is distributed and directed on to a turbine *T* by means of a four-way nozzle; the revolution of the turbine operates the propeller shaft by means of gearing, by which the speed is reduced to ordinary limits. Safety valves and a firing apparatus for igniting the rockets, are also provided. The steering is effected by means of two finely plaited line-cords, hooked to the yoke, and leading to two reels (each holding one mile) at the operating point. The movement of the rudder is effected by bringing an increased strain on one or other of the yoke-lines, by means of dynamometer and brakes. The position of the torpedo (the leader) at any time is shown by means of a rod *S* and disc fixed to the top of it.

This torpedo is intended to run on the surface of the water, and has a range of one mile, at a speed (estimated) of 24 knots per hour.

The *modus operandi* of this system is briefly as follows:—

The two torpedoes are started together, the leader *A* being slightly the faster of the two, tows *B* behind it.

Either or both may be charged, but *A* only is steered; while *B* is provided with a small diving rudder *a*, which is out of action so long as the wire towing rope *t*, 30 or 40 yards long, is taut.

On *A* striking a net, it becomes entangled therewith, and consequently the wire towing rope slackens, and the diving rudder of *B* comes into action, causing it to dive at an angle of 15°, and continuing on its way by its own motive power under the net until the towing line again becomes taut, it is caused to ascend, and to finally strike the ship below the water-line.

When there is no net, the same thing occurs, only the effect of the explosion is more damaging, as *B* then dives under the bottom, and explodes at a greater depth, and in contact with the weakest part of the ship.

THE BERDAN DIRIGIBLE TORPEDO.

PL. LXIX.

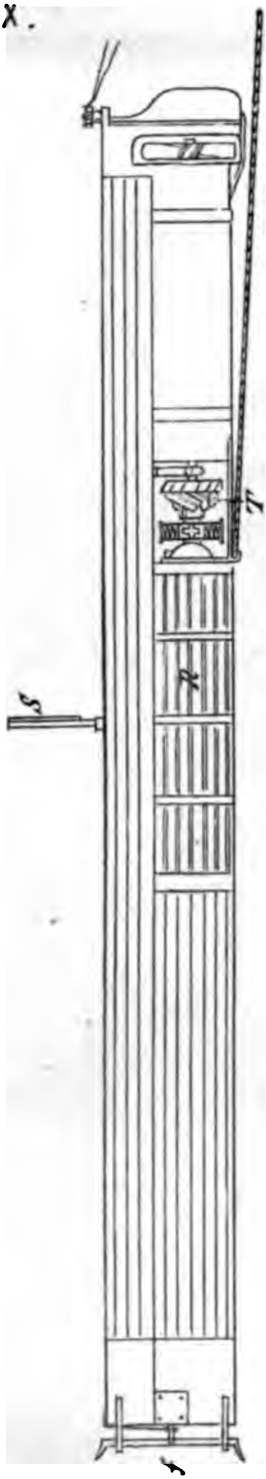
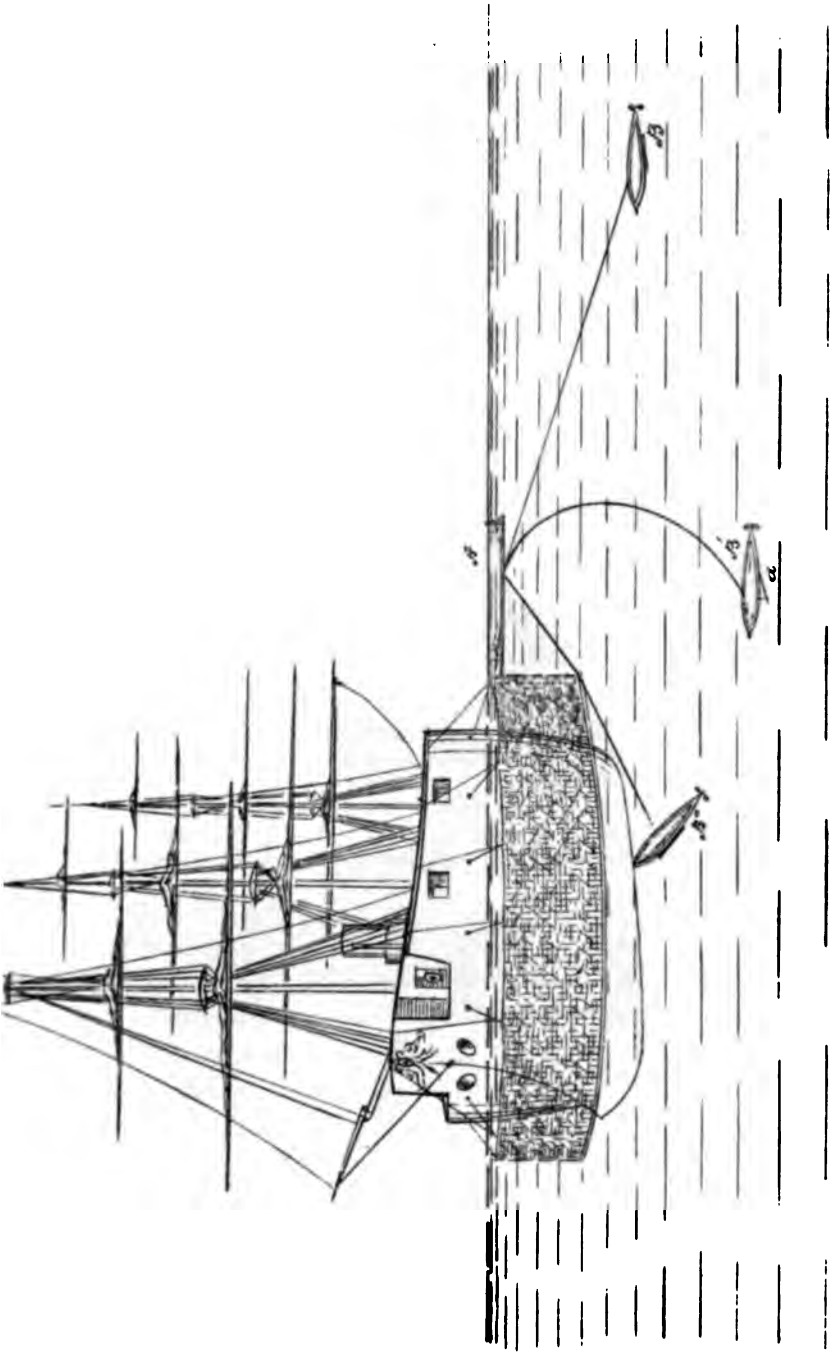


Fig. 1.

Fig. 2.

THE BERDAN DIRICIBLE TORPEDO.

PL LXX.



CHAPTER V.

CONTROLLABLE TORPEDOES (*continued*).

LOCOMOTIVE—"SIMS-EDISON"—"BRENNAN"—AUTO-MOBILE—"LAY"—"PATRICK"—"NORDENFELT."

D. Locomotive Torpedoes—1. Definition—2. Description of the Sims-Edison Type—3. Experiments with the Sims-Edison—4. Description of the Brennan Type—5. The original Brennan Torpedo—6. The present Brennan Torpedo—7. Method of Propulsion—8. The operation of Running—9. Present Position—9*a*. The Maxim Torpedo—10. The capabilities of the Locomotive Torpedo for Offence and Defence—11. Sims-Edison *v*. Brennan—E. Auto-Mobile Torpedoes—12. Definition—13. The Lay Type—14. The Improved Lay—15. The Lay-Haight and Patrick Types—16. Description of the Patrick—17. The Nordenfelt Type—18. The Auto-Mobile *v*. The Locomotive Type—19. Requirements of an effective Auto-Mobile Torpedo—20. Comparative merits determined by extent of their respective spheres of Action—21. An advantage claimed for the Locomotive Type—22. An effective Auto-Mobile Torpedo superior to the Brennan—23. Different methods of Submergence considered—24. The best method of Propulsion considered—25. Advantages of Electrical Propulsion—26. Their Comparative Merits for Naval Warfare—27. American Objections—28. Validity of Objections with present knowledge—29. Their use restricted to certain phases of Naval Warfare—30. The other Objections considered—31. Question of Size—32. Fault of Official Experiments—33. Methods of carrying them—34. The Torpedo of the future.

D.—LOCOMOTIVE TORPEDOES.

DEFINITION—By "Locomotive" *controllable* torpedoes are meant those whose *motive* power is developed at some position external to the weapons themselves, and to which they are in connection with, either by electrical, as in the case of the "Sims-Edison," or by mechanical means, as in the case of the "Brennan."

Description of the Sims-Edison Type.—The *Sims-Edison* locomotive torpedo is the outcome of the advance that has been made during the last few years in the application of *electrical* transmission of power for the propulsion of vehicles and vessels, and is unquestionably a very decided improvement on the original type, the "Ericsson" (1873); this latter weapon was propelled by compressed air conveyed to a motor in the torpedo by means of a tubular cable, but its short range, 300 feet, and slow speed, 4 knots, rendered it a most unserviceable weapon.

The *Sims-Edison* torpedo, shown at Pl. LXXII., Fig. 1, as now constructed, consists of a cylindrical hull of copper with conical ends, and is provided with a float, also of copper, filled with cotton rendered impervious to water; in cross section it is broader at the top than underneath, so that its buoyancy increases very rapidly with immersion.

The hull is rigidly connected with this float by steel rods, the foremost one of which, slanting to the rear and upwards *from* the nose of the former to that of the latter, enables it to cut through or dive under floating obstructions. Two guide rods provided with springs, so that they may give way when passing under a boom, are placed as usual on the float. A balanced rudder is fitted on the top of the after cone just before the propeller guide.

The propulsion is effected by means of a 20-light Weston dynamo situated at the operating station, and a Siemens motor fixed in the torpedo; the current of 30 ampères, E.M.F. 600 volts generated by the dynamo (by means of steam power) is conveyed to the torpedo through one insulated core, composed of twenty No. 20 copper wires, of a double cored cable, of which a quantity is reeled up in the torpedo.

The rudder is worked by means of two large electro-magnets operated by a portion of the main current switched into circuit with one or other of the magnets by the aid of a relay which is manipulated from the station by a small current transmitted through the second core composed of seven No. 23 copper wires.

There are two kinds of this weapon used at present designated by the amount of the cable each carries, viz. the *one* mile (A), and the *two* mile (B) torpedo.

Dimensions and particulars of these two weapons are as follows:—

Table XVI.

	A.	B.
Length	28 feet.	28 feet.
Diameter	18 inches.	21 inches.
Weight of hull	1·6 tons.	2 tons.
Length of cable	1 mile.	2 miles.
Charge	200 lbs.	400 lbs.
Speed	10½ knots.	10½ knots.
Submergence	3¾ feet.	5 feet.
Length of float	20 "	20 feet.
Buoyancy	400 lbs.	400 lbs.

Experiments with the Sims-Edison.—A most severe and exhaustive series of experiments have been carried out in America under the direction of General Abbot, U.S.A., since 1880, resulting in satisfactory results in every particular except in the matter of speed; amongst others may be mentioned the charging of a heavy anchored boom, and the riddling of its float by shrapnel and machine gun fire, and in both of these severe tests it proved most successful.

The question of higher speed is only of course a question of the transmission of more power, but this involves the use of a cable of larger diameter, consequently of greater weight, and requiring greater stowage room, or in other words a larger sized torpedo for the same length of cable; while as considerable trouble has been experienced in the paying out of the smaller cable at present in use, any increase in its size might possibly cause additional trouble in this respect.

Description of the Brennan type.—This invention has recently been brought prominently before the public by reason of its adoption by the English Government, and the large sum of money, £110,000, paid for its, so called, *secret*, and for the sole right of manufacture in England, and also through the illustrated articles lately published in the *Engineering* (London), purporting to give a full explanation of the manipulation of this torpedo, and strongly arguing against its adoption.

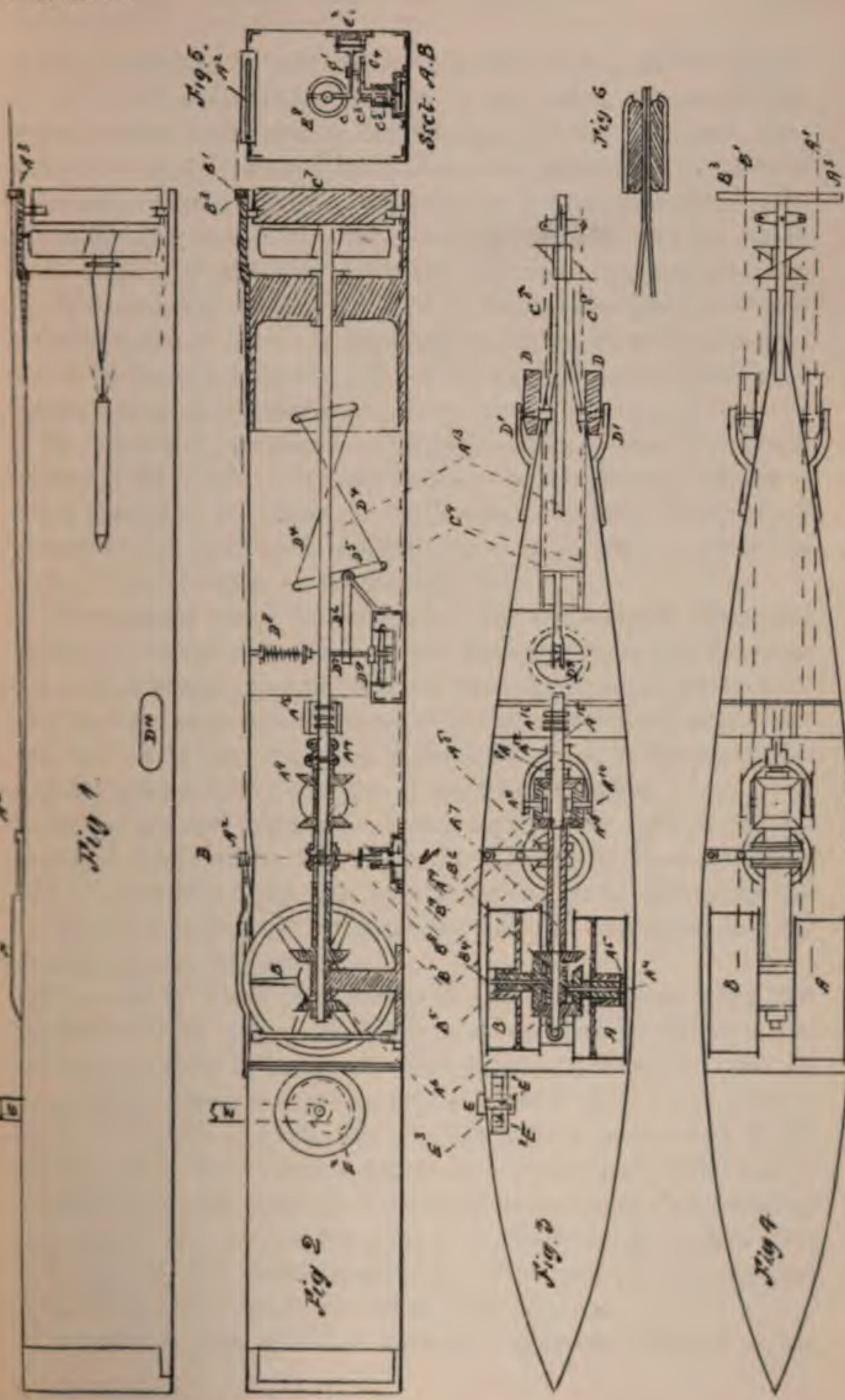
This torpedo was invented in 1876 by Mr. Brennan, of Melbourne, Australia, and was patented in England in the following year; it was brought to Chatham, the headquarters of the R. E. torpedo corps in 1881, after being favourably reported on by a committee of English Naval officers of the Australian squadron. It successfully passed through its initial trials at Chatham, and was provisionally adopted; the inventor was paid £5000, and an annual sum of £1000 for five years.

The Original Brennan Torpedo.—The considerable amount of interest taken in the *adoption of the Brennan* torpedo by the British Government, not so much because of the utility of this invention, but on account of the peculiarity of its method of propulsion, and also because of the very large sum of money paid for this weapon, has induced the author to include a description of this torpedo as set forth in Mr. Brennan's patent of 1877, as well as a description of a modified form of *Brennan* as stated in Mr. H. Maxim's patent of 1886, in addition to the description which has appeared in the *Engineering* of the improved R. E. (Brennan) torpedo.

At Pl. LIX. is shown drawings of the original *Brennan*, where Fig. 1 is a side elevation, Fig. 2 a longitudinal section, Fig. 3 a sectional plan, Fig. 4 a plan, Fig. 5 section on AB (Fig. 2), and Fig. 6 a section of A^2 (Fig. 1). A and B are the drums on which the wires A^1 and B^1 is wound. This wire passes between the lips A^2, the construction of which is clearly shown in Fig. 6, and also through guides A^3, A^3, at the stern, so as to prevent said wire from fouling either the rudder or the *propeller*. The drums are attached to mitre wheels A^5, B^5, respectively, which run loosely on their respective shafts A^4 and B^4. Mitre wheel A^5 gears into and drives another mitre wheel A^6, fitted near the end of solid shaft A^7. This solid shaft has a screw thread cut on its periphery at A^8, and carries another mitre wheel A^9, and a casting consisting of boss and spindles A^{10} and A^{11}, carrying mitre wheels A^{18} and A^{19}. This solid shaft is connected at A^{12} to the propeller shaft A^{13} by stem of fork A^{14}. A^{15} are collars fitting in recesses in the thrust bearing A^{16}; A^{17} is the propeller; B^4 carries a mitre wheel B^5, which gears into and drives another mitre wheel B^6, forming the end of hollow shaft B^7. This hollow shaft has two slots cut in it, one opposite the other, and both in opposition to the screw thread A^8, which slots are covered by a nut or collar B^8, made in two halves, and having a projecting screw thread cut on its inner face, as shown in detail sketch between the plan and the horizontal section, one being a face view and the other a side view of said collar. Said hollow shaft terminates in a mitre wheel B^9, which gears into wheels A^{18} and A^{19}. The groove on the outer periphery of nut or collar B^8 receives a stud C on the end of lever arm C^1, hinged to the side of the vessel at C^2. This lever arm carries a pin C^3, which works in a slot in lever arm C^4, connected to the top of vertical spindle C^5, at the bottom of which is a cross piece C^6. Each end of this cross piece is connected to opposite sides of the rudder C^7 by means of wires C^8 passing through tubes C^9. D, D, are fins consisting of strong metal plate, each fin supported by a spindle, the outer end of which is carried in bent arm D^1, and the inner end turned, tapered, and ground to fit a conical seat in the casting D^2. The inner end of these spindles is squared to fit into square holes in the rocking piece D^3; D^4, D^4, are wire rods connecting said rocking piece to cross piece D^5, operated by levers D^6,

THE ORIGINAL BRENNAN TORPEDO.

PL. LIX.



which is attached to vertical spindle D^7; D^8 is a coiled spring, and D^9 is a leather contrivance like a dry meter, exposed to the pressure of the water outside through hole D^{10}. E is a mast, consisting of a steel blade carrying a disc or flag to indicate its position. This blade, carrying a disc, is supported on a horizontal pin E^1 projecting from the side of the torpedo, which pin is held by one end of a coiled spring E^2, the other end being fastened to the containing box E^3. This spring is to allow the mast to give to the pressure of any obstruction, and to compel it to return to its upright position as soon as such obstruction is passed. H is a lid, which is screwed down with suitable water-tight packing.

The method of operation is as follows:—First, so far as regards the propulsion only. On each of the drums A and B a quantity of wire is wound, *four* times the length of the distance to which the torpedo is to be propelled; thus, if it is contemplated to propel it a quarter of a mile, a mile of wire is wound on each drum.

The wires are passed between the lips A^2, and through the guides A^3 and B^3, and fasten the ends to the respective stationary drums on shore. The torpedo is launched, and the engine started which is to work the *unwinding* reels or drums as near simultaneously as possible, with this result, that the vessel is propelled by the revolution of the propeller produced by the motion of the drums A and B.

If the torpedo requires to travel more to the right it can be compelled to do so by increasing the velocity of the shore drum, which is unwinding the wire from the drum B, or decreasing the velocity of the other, or by increasing one end and decreasing the other at one and the same time.

The way in which the guiding is effected is thus:—When the increased velocity is given to the drum B it imparts a quicker motion to the hollow shaft B^7 than that which is given to the solid shaft A^7, the result of which is that the nut or collar B^8 travels on the screw thread A^8 towards the drum B. As it travels it carries with it the stud C (which catches in the groove in its outer periphery), and so operates the hinged lever arm C^1, which in its turn moves the radiating lever arm C^4 by means of pin C^3, and so moves the cross piece C^6 at the bottom of the vertical spindle C^5. This cross piece in its turn moves the rudder through connecting wires C^8.

In order to give either an upward or downward direction to the torpedo, as may be required, the nose of the fins *D, D*, is raised or depressed by means of the leather contrivance D^9, which is pressed upwards whenever the pressure of the water is greater than that of the coiled spring D^8; that is to say, whenever the vessel sinks too deep the contrivance D^9 is pressed upward, with this result, that it depresses the nose of the fins *D, D*, through the intermediate gearing shown in longitudinal and horizontal sections, and causes the bow of the torpedo to rise and travel upwards until the equilibrium between the pressure of the water and that of the coiled spring D^8 is restored. An opposite effect is necessarily produced if the torpedo rises too high.

The present Brennan Torpedo.—The present *Brennan*, perfected under the auspices of the Chatham torpedo authorities, is stated to have a speed of 20 miles per hour, a range of 1½ miles, and to be capable of lateral control in a limited degree. It is run at a depth of 10 feet below the surface by a modified arrangement of the "Whitehead" submerging apparatus, and it is provided with two propellers *P, P′*, Pl. LXXI., revolving in opposite directions on the same line of shafting on the same plan of bevel wheel gearing *D* as devised for the "Whitehead." The mode of propulsion and of lateral steering adopted in the *Brennan* is a distinct novelty, of which the following brief description is taken from the *Engineering*.

Method of Propulsion.—The propulsion is effected by the rapid unwinding of two steel piano wires *w, w′* from two drums or reels *A* and *B*, Pl. LXXI., Fig. 1, placed in the interior of the torpedo, and connected respectively to the two propeller shafts, s, s^1, thereby causing the two propellers to revolve at a high rate of speed, and consequently forcing the torpedo through the water. The unwinding of these two wires is effected by means of a powerful steam winding engine, Pl. LXXI *A*., placed at the operating station on shore.

An apparent paradox is involved in this form of propulsion, in the fact that the harder the torpedo is pulled back the faster it goes ahead; but on consideration it will be seen that by hauling in the wires at a certain rate, a corresponding rate of revolution is imparted to the drums, which are fixed to the propeller shafts in the torpedo, and so to the two propellers, which are thereby capable of developing a certain horse-power. If this power thus developed be then sufficient to overcome the retarding strain on the wires, and to leave a margin of thrust, then the torpedo must be propelled through the

THE BRENNAN TORPEDO.

PL. LXXI

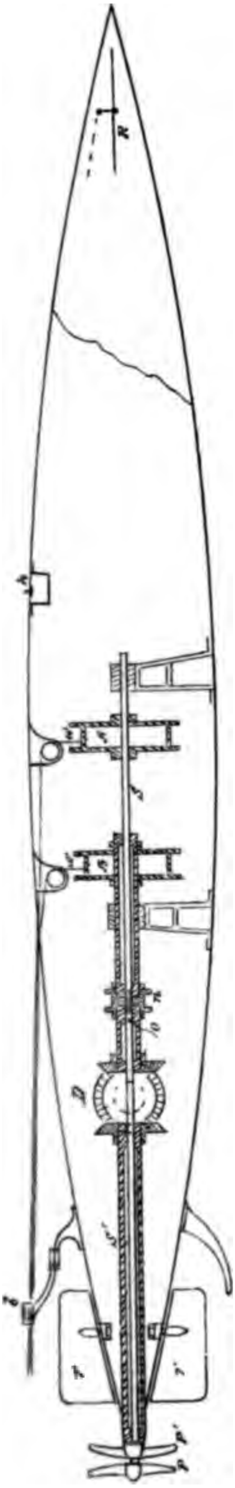


Fig. 1.

Fig. 2.

water; and the only limit to its speed is apparently the strength of the wires.

The movement of the vertical rudder *r*, *r*, for laterally steering this weapon is effected by imparting to the two torpedo drums a different rate of revolution, *i.e.* either increasing the speed of one, or decreasing the speed of the other drum; a forked lever *l* attached to the rudder yoke is brought into connection at its inner end with a grooved collar *n*; this collar is provided with an internal screw thread, and engages through a longitudinal slot in the outer hollow propeller shaft *s'* with a screw thread *o* cut on the inner solid shaft. So long as the speed *s* of the two propeller shafts, which up to a certain point revolve in the same direction, are equal, the collar and the shafts will revolve together; but the instant a difference of speed is imparted to the two drums, or two propeller shafts, the collar will be forced to travel either aft or forward, causing the rudder to be moved to port, or starboard, depending upon the nature of the screw threads, and which of the shafts is increased or decreased in speed.

The shore winding engine designed at Chatham, and constructed by Messrs. Yarrow & Co., shown at Pl. LXXI*A*., consists of two drums 3 ft. in diameter, driven by a pair of direct-acting high-pressure engines running at a great speed. Each cylinder is cast with the column under it, the latter being very strong and of such a form as to enclose the main working parts of the engine, and to prevent the wires from becoming entangled with any part of the engines in the event of either or both of them breaking. The engines are fitted with valve gear, which can be reversed or linked up so as to work expansively. The steam is admitted by means of a valve common to both engines, besides which a governor is also fitted. The drums, running loose on the shafting, are connected by a "jack-in-the-box" arrangement, by which their respective speeds can be regulated by means of a foot-brake without altering the speed of the engines. This "jack-in-the-box" is arranged as follows: Cast solid on or bolted to each drum is a mitre wheel, and connecting these two mitre wheels are two smaller ones, revolving on their own centres, fixed on a carrier which is keyed to the main shaft. As soon as the main engine starts, the two small mitre wheels, which are in one with the shaft, are revolved with it, and carry round with them the two larger mitre wheels and consequently the drums as well. Hence it will be seen that on the brake being applied to one of the drums, the small mitre wheels will be thereby caused to revolve round their own centres, the effect of which is to increase the speed of the other drum. In proportion as the speed of the one decreases the other increases. The columns are braced together under the cylinders by another casting, and the whole stands upon a cast-iron sole-plate, thus making a very rigid formation. The engine is capable of working up to 100 indicated horse-power.

The Operation of Running.—The operation of running this torpedo is as follows:—

The torpedo is placed on a lauching carriage, which is constructed in such a manner that the torpedo is automatically set free, and launched or pitched clear of it into the water, on the carriage reaching the desired position on the line of rails, which are laid on an incline to the water's edge; the hydrostatic valve is then set with the bow horizontal rudders *R, R* at the proper deflection upwards for the particular depth and speed it is intended to run the torpedo at, the speed being regulated by the number of revolutions given to the winding-in drums. The shore ends of the two wires are taken from the torpedo, secured to their respective winding drums, and one or two turns of the wires wound on. The carriage with the torpedo is then run down the incline, and the latter launched automatically into the water, the winding engines being at the same instant started. The torpedo then runs the required course and distance, being maintained in a straight direction for the object aimed at by the necessary movement of the stern vertical rudders to port or starboard; its course being indicated to the observer by a single steel telescopic mast surmounted by a disc or flag, or as shown in Pl. LXXI., Fig. 1, by the emission of phosphorescent light and smoke from *h*.

In the manipulation of the torpedo at Sheerness the wires are led *above* water from it to the engine room situated in the fort at a considerable height above the water; if this is a necessary feature it must obviously be detrimental to its practical application for general use, as the wires might be readily broken by the enemy, or accidentally damaged by a vessel passing between the torpedo and the shore; the latter mishap actually occurred during one of the experimental runs of this weapon.

Present Position.—The following description of the present position

PL. LXXI. A

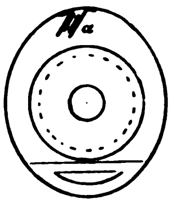


Fig. 1.

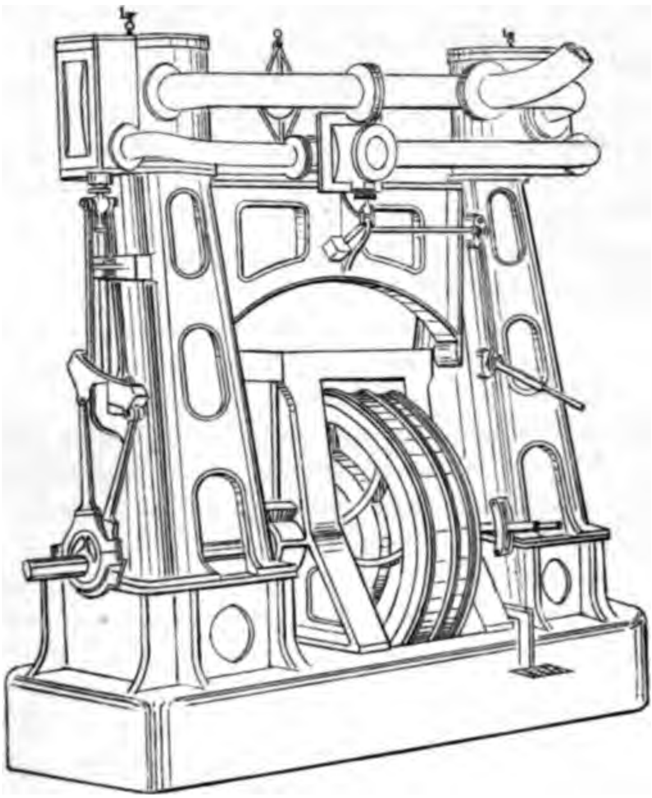


Fig. 2.

of the "Brennan" is taken from the *Army and Navy Gazette*, November 26th, 1887.

". . . . Accuracy of direction in a vertical plane has been obtained by an entirely new depth-regulating apparatus, which is one of the principal 'secrets' of the torpedo. Another is the contrivance for exploding, which is also quite new and extremely sensitive. There is no pistol, as in the Whitehead and Woolwich varieties; but the exploding gear is contained inside the fish, which is of finer lines at both ends than has hitherto been usual. One of the most perplexing difficulties that arose in the early experiments was the excessive rolling motion of the torpedo; but this has been completely overcome by a judicious alteration in the position of the driving-wires. There are automatic indicators that trace diagrams recording accurately the variations in depth, the rolling, every alteration of both sets of rudders, and the speed at any given moment of each run. The arrangement for uniformity of depth is in no way affected by any change of speed. The light steel mast, carrying the small flag by which the course of the torpedo is known to the operator, absorbs four knots of the speed by its resistance; but as yet no contrivance has been invented to supersede it, and Mr. Brennan is not hopeful that one ever will be. For night work the mast carries a small electric-lamp of 16 candle-power, enclosed in a funnel-shaped shade, the apex, of course, pointing towards the enemy. The fixed engines for driving the torpedo at the various points on the coast where it may be decided to establish a station will be of 100 horse-power. *All idea of using it on board ship has long been given up.*

The Maxim Torpedo.—The following description of this torpedo, which is a modification of the *Brennan*, has been taken from Mr. H. Maxim's patent of 1886. This same patent also includes the description of a torpedo on a similar system, but designed to be propelled and manipulated through the agency of a *single* wire.

The Maxim *two*-wire torpedo is shown in Pl. LXXI*b*., where Fig. 1 is a general view, Fig. 2 a plan, and Fig. 3 a vertical section.

A is the hull; A^1 the pipe or fairlead for the wires; B^1, B, the propellers; E^3 the rudder; L a signal oscillating mast fixed in a socket L^1, firmly attached to one of the side wings or fins H.

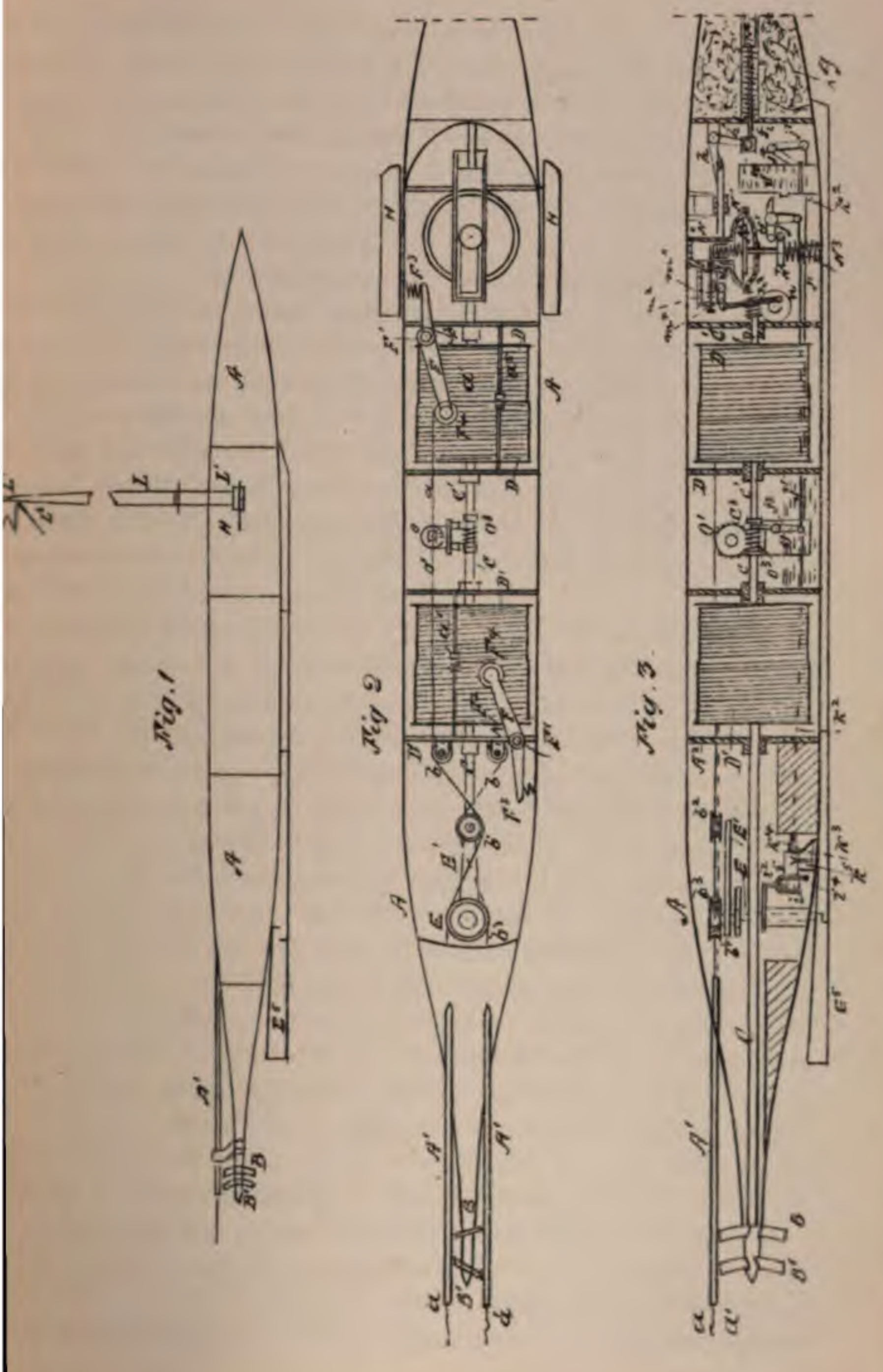
L^3 is a plate which is pivoted at L^4 to the mast L, and is held down against a shoulder L^5 on the said mast by means of a spring L^6, so that it will yield when subjected to the action of a wave. This plate is designed to counteract any tendency of the torpedo to make sudden plunges by reason of the action of the waves thereon, or from other causes. Should the torpedo make a plunge it will be prevented from sinking below the plate L^3 by the action of the water thereon, which will compress the spring L^6, and will at the same time move the mast L, and consequently the fins or wings H, into the proper position to cause the torpedo to rise in the water.

Two wires a, a^1, are employed for effecting the various operations necessary in manœuvring the torpedo. A reel or drum D is fixed upon the propeller-shaft C^1, and another reel or drum D^1 is fixed upon the propeller-shaft C. Each of the wires from these drums is passed first around a guide-pulley a^1 fitted to slide longitudinally upon a stationary rod a^6, and then around a pulley F^4, carried by a brake-lever F. The wires a, a^1 are also passed around guide-pulleys b, carried by brackets attached to the bulkhead A^2. The said wires are then conducted around opposite sides of two pulleys b^1, b^2, fitted to rotate upon a pin or stud fixed in the forward end of the lever or tiller E^1; they are then crossed as shown, and passed around opposite sides of two pulleys b^3, b^4, fitted to rotate upon the upper end of the rudder post E. The said wires are then conducted through pipes A^1 to any suitable winding apparatus on the land or on a ship or vessel.

The rear end of the rod K^2 is coupled to the nut K^3, and is designed to be operated by means of a ratchet and pawl mechanism. The forward end of the said rod K^2 is coupled to the tail piece J^7 of a catch J^4, which is pivoted to the shell or casing A. This catch engages with a shoulder or projection on a plunger J^{10}, which is fitted to slide vertically upon a hollow upright or standard secured to the shell or casing A, and which is acted upon by a spring.

N is a diaphragm which is fixed in a casing N^1, and is firmly connected with a spindle N^2. The upper half of the casing N^1 is connected by means of a hollow extension N^1 with the shell or casing A, and is open for the admission of water from the outside of the torpedo, so that one side of the diaphragm N may be subjected to the pressure of the water. This pressure is counteracted by a spring N^3, one end of which bears against the shell or casing A, whilst its other end bears against a shoulder or collar N^4 on the spindle N^2 of the diaphragm. j is a short link, one end of which is coupled to

PL. LXXI. b



the collar N^4, the other end being coupled to one arm of a bell-crank lever H^7, fixed upon the shaft H^1, which carries the side wings or fins H. To the lower end of the other arm of the bell-crank lever H^7 is coupled the forward end of a rod j^1, the rear end of which is coupled to a lever j^2, arranged to operate a clutch O^3, for the purpose of putting an oscillating pump O in gear with one or the other of the propeller shafts C, C^1, as desired.

The pump O is arranged to be operated by means of a worm-wheel O^1 mounted on the shaft, and driven by a worm or tangent screw O^3, formed or fixed on the movable part of the clutch C^3, which is fitted to slide on the shaft C^1. The piston or plunger of the said pump is connected by a rod with a crank-pin fixed in the worm-wheel O^1; and the said pump is so arranged that when driven by the shaft C^1 it will deliver water into the torpedo, and, when driven by the shaft C, it will eject water from the torpedo. By these means the torpedo may be caused to sink to a certain depth below the surface of the water, and to remain at this depth.

The diaphragm N and the spring N^3 are so arranged that the pressure of water on the said diaphragm will tend to move it in one direction, and the said spring will tend to move it in the reverse direction. If the spring is of sufficient strength to resist a pressure on the diaphragm of, say 5 pounds per square inch, the torpedo will sink until it reaches a depth of about 10 feet below the surface of the water; the spring will then be compressed by the pressure of the water, and the diaphragm and its spindle will move downwards. In this downward movement the bell-crank lever H^7 will be turned upon its pivot, and will put the worm O^3 in gear with the shaft C, so that the water will be pumped out of the torpedo, and the sinking of the latter to a greater depth will be prevented. Moreover, if the torpedo descends below the desired depth, the shaft H^1 will be turned so as to bring the side wings or fins into position to cause the torpedo to rise in the water. Should the torpedo rise above the desired depth the action of the said pump will be reversed, and the said wings or fins adjusted to cause the torpedo to sink, the spring N^3 being enabled to move the diaphragm against the diminished pressure of the water.

To provide for enabling a torpedo to move out from the shore in shallow water and then sink to a greater depth, or, in other words, to provide for the sinking of the torpedo after a predetermined number of revolutions of the reel or drum *D*, a spring is arranged to act upon the diaphragm *N* in the same direction as the pressure of the water. The outer end of this spring bears against a hollow piston fitted to slide up and down in the extension N^1, and perforated to permit the entrance of water into the casing N^1. The said spring is held in compression by means of a sliding bar m^1, which passes through a stuffing box in the extension N^1 of the casing N^1. The outer end of the bar is supported in a bracket m^1 attached to the extension N^1. The sliding bar m^1 is provided with ratchet-teeth m^2, and has an intermittent motion imparted to it by means of a pawl which is pivoted to the short arm of a bell-crank lever m^4; this lever is pivoted to the shell or casing *A*, and has its long arm connected by a rod *n* to a crank-pin fixed in a worm-wheel n^1, geared with a worm or tangent screw n^2 formed or fixed on the shaft C^1. It will therefore be seen that as soon as the reel or drum has revolved a sufficient number of times to move the sliding bar m^1 out of engagement with the spring the latter will expand, and its pressure being thus removed from the diaphragm *N*, the latter will be forced outwards by the spring N^3, and will, through the medium of the lever H^7, turn the wings or fins *H* so as to cause the torpedo to sink deeper in the water. This movement of the lever H^7 will also put the pumps *O* in gear with the shaft C^1, so that water will thereby be also forced into the torpedo. The torpedo will then continue to sink until the pressure upon the diaphragm, due to the increased head of water, is greater than the force exerted by the spring N^3, after which the torpedo will remain at the desired depth.

To render the torpedo safe to handle, that is to say, to prevent the explosion thereof until after it has travelled a certain distance through the water, a device is provided which necessitates the turning of the propellers a certain number of times before the priming charge will be in position to be struck by the firing pin or striker. The sliding bar m^1 has attached thereto one end of a rod, which is carried in a bracket attached to the shell or casing *A*. The forward end of this rod engages with one arm of a bell-crank lever *h*, pivoted to a bracket secured to the foremost division plate or bulkhead. The other arm of the said lever is forked, and extends between shoulders or collars on the rod f^2, so that it holds the priming charge out of reach of the firing pin or striker. When the torpedo has moved a certain distance through the water the sliding bar will be disengaged from the lever *h*, and the priming will be moved by the spring g^1 into position to be struck by the firing pin as soon as the torpedo comes in contact with a ship or other object against which it is directed.

Should the torpedo fail to strike an object against which it is directed the torpedo can be brought to the top of the water by moving the rudder a certain number of times alternately from port to starboard, and *vice versâ*, so as to operate the ratchet lever i, and thus draw back the rod K^2 and release the catch J^4 from the shoulder. The spring will then force the hollow plunger J^{10} upward, so that a projection thereon will strike the arm of the lever H^7, and thus turn the side wings or fins H into position to cause the torpedo to rise, and at the same time start the pump O in the proper direction to pump water out of the torpedo and strike the bell-crank lever h, and thereby draw the priming out of reach of the firing pin or striker.

The steering or movement of the rudder is effected by putting different stresses upon the different wires, and thus compelling the pulleys b^1, b^2, and lever or tiller E^1, to move either to port or to starboard, or, in other words, by rotating the propeller shafts at different velocities.

The Capabilities of the Locomotive Torpedo for Offence and Defence.—For offensive purposes, *i.e.* for use as a ship weapon, both the "Sims-Edison" (electrical), and the "Brennan" (mechanical), are considered unsuitable, the former by an American Naval Commission, and the latter by the English authorities.

In so far as the "Brennan" is concerned, its mode of propulsion condemns it as a practical weapon for ship use; but it would be feasible, though possibly difficulties in its application would occur in so doing, were it not for its want of speed, for the "Sims-Edison" to be so employed.

As a ship weapon the great defect of this class (Locomotive) of torpedo, when employed for harbour defence, viz., the necessity of operating them from a fixed base, becomes obviated, because the ship itself would then be the operating station; the "Brennan" however would require the vessel manipulating it to be stationary at the time, which alone constitutes a fatal objection to its being considered as a naval torpedo. For the purposes of harbour defence, both the "Sims-Edison" and the "Brennan" are decidedly superior to the "Whitehead" and its kindred, but both possess the before-mentioned very serious disadvantage of the development of their motive power at a station external to the weapon itself (whose position would most assuredly be known to the enemy), and therefore their sphere of attack is circumscribed, and limited to the length of electric cable or wire carried.

Sims-Edison v. *Brennan*.—The comparative merits of these two "Locomotive" torpedoes will be best understood by considering the characteristic features of this class as fulfilled by both of them, in the following manner:—

TABLE XVII.

Characteristic Features.	Sims-Edison.	Brennan.
Motive Power	Electrical. Developed at the operating station, and practically unlimited as to power and duration.	Mechanical.
Range	1 to 2 miles; depending on size of torpedo. Limited to the length of cable or wire carried, and the distance at which it is feasible to keep the direction marks of the torpedo in sight.	1½ miles; depending on size of torpedo.
Submergence	By means of a float; from 4 to 6 feet, according to size of torpedo.	Whitehead's principle of Automatic Hydro-pneumatic Apparatus, 10 feet.
Controllability	Starting and stopping the engines. Absolute in lateral direction. By means of second core in the insulated cable, the explosion of the charge can be effected "at will" as well as by "contact;" and the guide rods or direction marks raised and lowered.	Starting and stopping the engines at any time not so easily arranged for; while on being stopped this torpedo would rise to the surface, and would not regain its proper depth and regularity of submersion for some time after being re-started. Limited in lateral direction.
Speed	10 knots.	18 knots.

In so far as *controllability* is concerned, the "Sims-Edison" is very much superior to the "Brennan," because the latter can practically only be given the necessary amount of alteration in direction to enable it to keep on a straight course, and therefore is unable to run at right angles to its set course, or on an opposite course, or in other words is unable to follow a ship who may and probably would be under these circumstances constantly altering her direction.

While the "Brennan" has but one guide rod to show its direction at any time to the operator, the "Sims-Edison" is provided with two such guide rods; one rod is however doubtless sufficient for the limited amount of steering possible with the former.

As to submergence, the "Brennan" is superior to the "Sims-Edison" in respect to the actual amount, but is inferior to the latter in regard to regularity of submersion, as no automatic apparatus for regulating the depth can be as sure as a fixed float.

The effect of the explosion of 200 lbs. of dynamite in actual contact with a vessel 4 feet below the water-line, though not producing so serious a result as at 10 feet, would yet be very severe, and possibly sufficiently so in most cases.

The "Sims-Edison" is very much inferior to the "Brennan" in the matter of speed, but even with this drawback it is a question whether the "Sims-Edison" is not a more useful weapon of the two for purely *harbour defence,* especially the protection of narrow entrances, owing to its application being simpler and more practicable (no wires leading from the torpedo *above* water to the operating station), and to its possessing, as compared with the "Brennan," *unlimited* range of lateral direction.

E.—AUTO-MOBILE TORPEDOES.

Definition.—By "Auto-mobile" *controllable* torpedoes is meant those in which the motive power is self-contained.

The "Lay" Type.—The *Lay* was the first controllable torpedo of this type brought into actual use, and it has been more universally tried than any other torpedo extant excepting the "Whitehead"; while it has had many imitators, amongst which may be mentioned as the more important, the "Lay-Haight," and the "Patrick." The original form of *Lay* was before the world for some eighteen years, during which time it was experimented upon by different naval and military commissions of the United States, Holland, Russia, China, and Turkey, but failed to receive adoption, except in a partial sense by Russia, who possesses ten of these weapons, and all the necessary machinery for constructing them, and by the United States, where some are used by their Torpedo school for experimental purposes.

The *Lay* was also used by the Peruvians in the Peru-Chilian struggle in 1880, but, owing to want of proper treatment, it was not successful.

The *Lay* in its original form failed to secure general adoption, principally by reason of its lack of speed, which, in the one used in the experiments of different countries, was only some 9 miles per hour; also owing to its being a surface torpedo; while further objections have been raised on the score of its motive power (carbonic acid gas), being liable to premature explosion, and being troublesome to develop.

In so far, however, as controllability was concerned, the *Lay* was most favourably reported upon, and was entirely successful.

The *Lay* in its original form has been so completely described, and as it has also been superseded by improved types, any further description of it is unnecessary.

Improved "Lay."—The following particulars and brief description of the Improved *Lay* is taken from the General Information Series, No. VI.:—"The principal point of difference between this and other similar weapons is in having the propellers forward, in a recess 3 feet from the bow; the object being to render the torpedo more amenable to control. The recess nearly divides the explosive chamber from the rest of the hull, being entirely open except at the top; the after side is bevelled away to give passage for the wash of the propellers in the upper part of their revolution. The screws are of peculiar design and application; the two are on a common shaft, which runs through the recess close to the bottom; the upper part of the revolution is within the recess, and the lower part entirely in the solid water underneath. In each propeller the two blades, instead of being on opposite sides of the shaft, are close together, the leading edge of one coming just behind the following edge of the other. One propeller is rigidly attached to the shaft, the other is loose upon it, but made to revolve with the former by an interlocking boss. Normally the two sets of blades are folded together, covering a sector of about 70°, and stand upright within the recess, protected from all injury. On starting the engine the one attached to the shaft begins to turn, and when it has made half a revolution its boss engages that of the other, after which the two revolve together, their blades being in opposite sectors of the disk of revolution.

"The torpedo is cylindrical, with a short, conical head and vertical wedge stern, 23 feet long, 18 inches in diameter, and said to weigh about 1¼ tons; it moves at the surface and carries 200 pounds of explosive in the forward cone. A vertical rudder is hung aft, actuated by an electrically controlled gas engine, and a pipe projects astern, through which the engines exhaust and the cable is paid out. There are arrangements by which it can be submerged by admitting water, which can afterwards be expelled by the gas pressure. The power is applied through a spherical engine, and a speed of 16 knots is claimed, with a range of 2 miles. At a public trial at Brightlingsea, England, in March, 1887, it heeled over so as to throw the propellers partly out of water, which prevented a successful performance; the causes of this were apparently temporary and may probably be remedied."

The Lay-Haight and Patrick Types.—These two torpedoes are so very similar that a description of one of them will suffice; both are submerged by means of a long narrow float extending some distance abaft the stern, and both have as their motive power carbonic acid gas drawn off in a liquid state from the reservoir.*

Description of the Patrick.—The following description of the *Patrick* is taken from General Information Series, No. VI.

"The float is fusiform, 41 feet long, with a maximum diameter of 12 inches; it is made of sheet copper $\frac{1}{8}$ inch thick, filled with lamp black, and carries two guide rods with flags; this float is practically indestructible by mechanical gun fire.

"The torpedo, made of the same metal as the float, and rigidly connected with it, is also fusiform, 36 feet long, and 22 inches in diameter. The nose projects, a short distance forward of the float, the latter extending well astern to correct the tendency to bury aft. The propeller is two-bladed, on a hollow shaft, through which the cable is paid out. The acid, drawn in liquid form from the bottom of the flask, is taken through copper piping in the bottoms of the heaters. These heaters are copper cylinders containing dilute sulphuric acid, each having a cylindrical trough in the top holding the lime; the latter is divided longitudinally into two parts, kept closed by a series of hooks on a common rod; which rod is connected with a piston in a cylinder outside the heater. A pipe leads from the steering-engine to this cylinder, and by putting the helm to port (before starting the main engines), gas is admitted to it, drawing back the rod, freeing the two parts of the trough, which are then forced apart by springs, and dumping the lime into the sulphuric acid.

"The propelling engines are of the 'diamond' type, six double-

* A description of the Lay or Wood-Haight torpedo is given in the Appendix, at page 325.

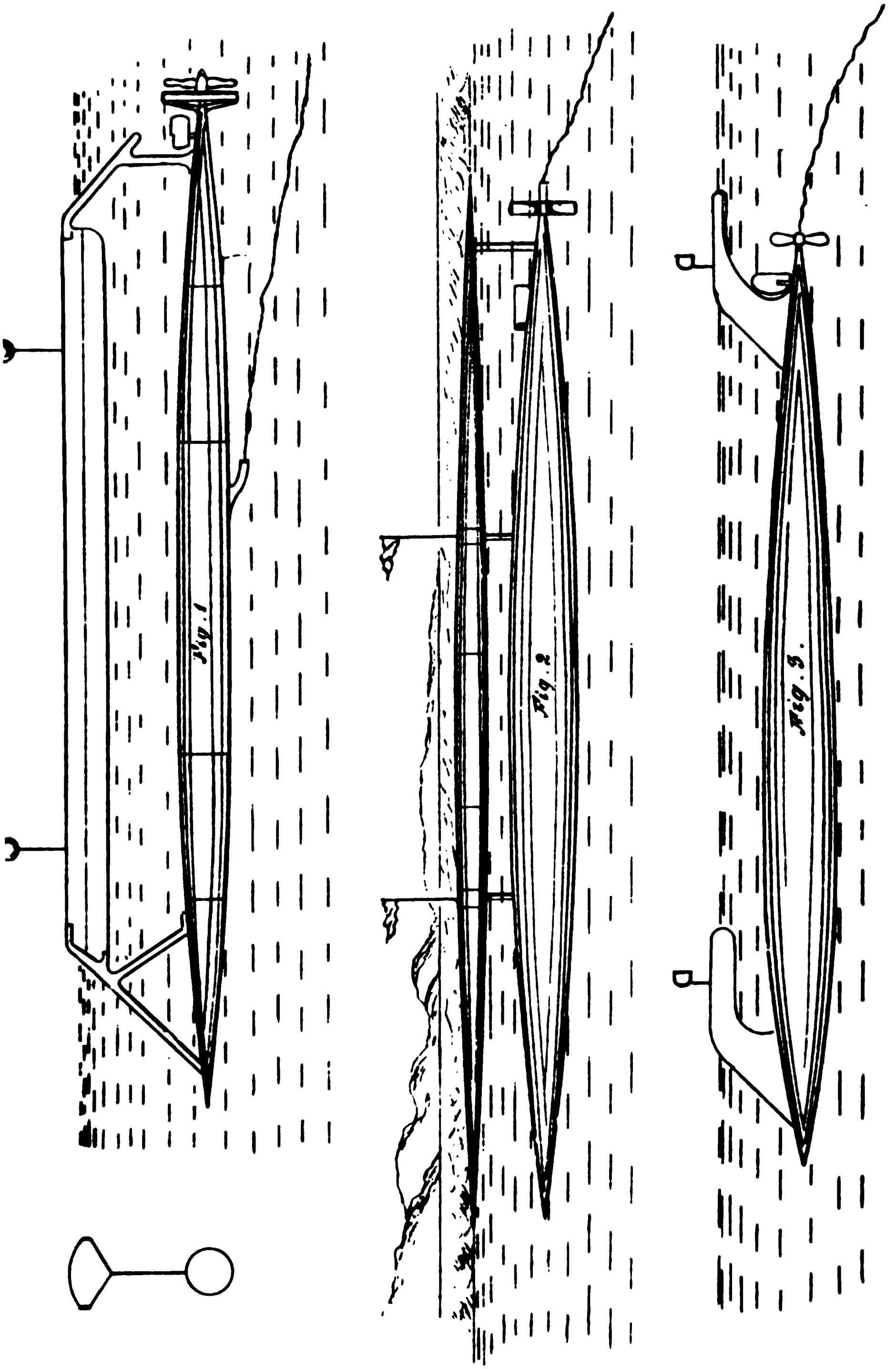
acting cylinders being grouped longitudinally about a central shaft, friction rollers attached to their cross-heads working in a zigzag cam groove on the surface of a drum attached rigidly to the shaft. They exhaust through the hollow shaft, and have made as high as 1100 revolutions. The rudder is balanced and placed forward of the propeller, on top of the shell. With the helm at 'steady,' the rudder is slightly to starboard, to counteract the throw of the propeller. 'A charge of 200 pounds of dynamite is carried, which is fired electrically at will or by contact. To perform the functions of start, stop, starboard, port, and fire, a two-wire cable is used in connection with eighty Bunsen's cells arranged in series. The cable is about 7000 feet long, with a diameter of nine sixty-fourths of an inch. The whole outfit weighs 4700 pounds; the torpedo proper weighing 3800 on a displacement of 3400 pounds. During various trials in America in the summer of 1886, the speed was found to be 16½ to 17 knots for a mile per hour; on one occasion the first half mile was made at the rate of 19½ knots. It also obeyed the helm promptly, and was easily guided."

The "Nordenfelt" type.—The *Nordenfelt* torpedo possesses a peculiar interest by reason of its being propelled by electrical power developed within the torpedo itself, and by this alone an important difference is constituted between it and all other torpedoes heretofore described.

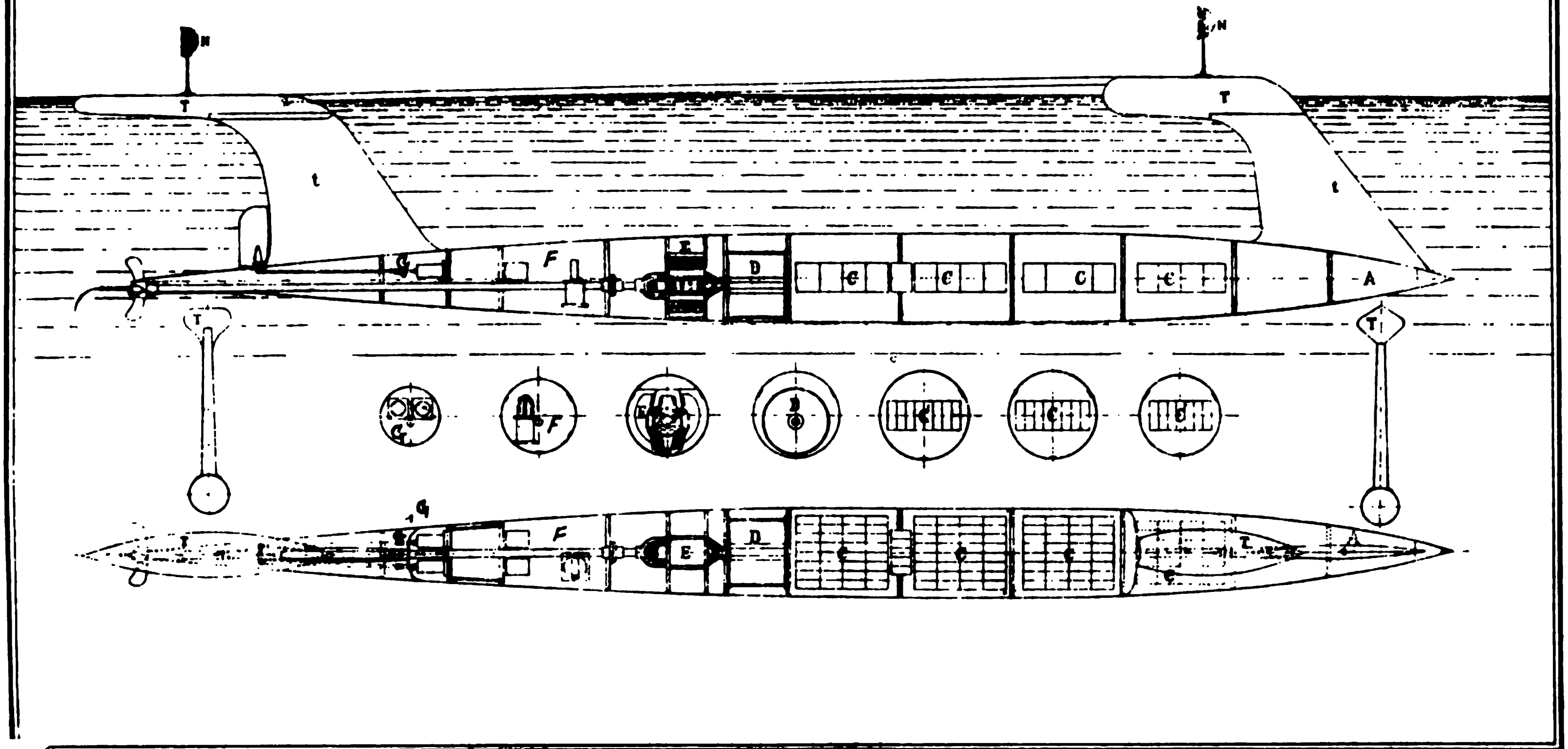
This weapon is the outcome of the development of the use of electrical accumulators, or secondary batteries for the propulsion of boats; but by reason of the great difference which exists between the conditions under which this motive power is required to act for the propulsion of a boat, and of a torpedo in the matter of duration of time, in the former case counted by hours, in the latter by minutes, a far more rapid advance has been possible in the improvement of the accumulator, and of the electro-motor, both electrically and mechanically, for the latter than for the former purpose.

For instance, the electro-motor has been reduced 43 per cent. in weight, for the same power or output, and the accumulator 42 per cent. for the same output, as compared with the best motor and accumulator obtainable in 1884, and it is in this matter of weight that this mode of propulsion has been hitherto considered impracticable in connection with torpedoes where high speed is a desirable and necessary feature.

PL. LXXII.



PL. LXXII.



The following is a brief description of the newly designed "Nordenfelt":—

Length	35 feet.
Diameter	29 inches.
Weight	2½ tons.
Charge	300 lbs. dynamite.
Range or Length of Cable . . .	2 miles.
Speed	16 knots.
Submergence	4 feet.

Details of the mode of propulsion and manipulation of this torpedo have not yet been made public.

The submergence of this weapon is also a distinct feature of its own, and is obtained by means of a small bow and stern fin, *supported by*, not supporting the torpedo, the latter having by itself, *i.e.* without the fins, a power of flotation, so that it requires the weight of the fins to sink it to the proper depth, and thus should any portion of the fins be knocked away by gun fire, this would only cause the torpedo to lessen its submergence, but not to risk its sinking.

The fin plates which carry the fins form part of the hull, and are of great structural strength, and with the fins, of special form to allow the torpedo to charge without harm booms and such like obstructions.

A general view of the "Nordenfelt" is shown at Pl. LXXII., Fig. 3, where it may be compared with the "Sims Edison," Fig. 1, and "Lay-Haight" or "Patrick" Fig. 2, in so far as external appearance is concerned, and at Pl. LXXII*a*. a vertical section, plan, and various cross sections of this electrical torpedo is given. *A* is the charge chamber: *C, C, C, C,* the motive power (accumulators) chambers: *D* the cable chamber: *E* the motor chamber: *F* the controlling instruments chamber: *G* the steering power chamber: *T, T* the fins: *t, t* the fin plates: *N, N* the directing points, containing an electric light for night runs.

The "Auto-Mobile" v. *the "Locomotive" type.*—To institute a comparison between the "Auto-mobile" and "Locomotive" type of *controllable* torpedo is a somewhat difficult matter, due to the fact that at present no pattern of the former type has been adopted, and therefore the question of the comparative merits and demerits of these two classes can only be discussed by supposing there to be an "Auto-mobile" torpedo in existence capable of fairly fulfilling all the requirements of such a weapon intended for *harbour* defence.

Requirements of an effective Auto-mobile Torpedo.—These requirements may be stated as follows:—The motive power being contained within the torpedo, and therefore access to it for any purpose being impossible when closed up, *i.e.* when ready for use, and, during a run, it should be of such a nature that but little deterioration of its power should occur after being closed up for a considerable time; it should be perfectly safe to handle; it should be capable of being readily restored to its normal power at any time; further, it should be capable of maintaining the full power during the whole of the run, *i.e.* the speed should be as great at the end as at the commencement. The speed should be at least 16 knots per hour. The range should be at least 4000 yards, that is to say, a run out and home of 2000 yards, with the capability of a full length run over the longer distance. A submergence of hull, such that the centre of the charge shall be 3 feet or more below the surface of the water, effected by automatic means, such as is adopted in the "Whitehead," or if by a float, or fins, such that their being damaged by gun fire, or in charging a floating boom, &c., should not render the torpedo likely to sink.

Comparative Merits determined by the Extent of their respective Spheres of Action.—With, then, a "Locomotive," and an "Automobile" controllable torpedo, possessing in an equal measure the aforesaid requirements as to speed, range, and submergence, and the latter that of motive power, the question as to which is the most suitable type depends entirely on the matter, not of the comparative range, but of the comparative sphere of action of these two weapons, a matter which may be summed up in two words, viz., *Limited* for the "Locomotive," and *Unlimited* for the "Auto-mobile."

The sphere of action of the "Locomotive" type, such as the "Sims-Edison" and the "Brennan," is *limited*, as it must be worked from a fixed point, by its range, *i.e.* by the length of cable, or wire carried; while, though as is claimed for these weapons, their motive power is practically unlimited as to time, yet their actual range of action depends on the distance at which they can be seen by the operator for enabling him to control them: in day-time this would not be further than some 3000 yards, while at night-time, though lights may be used on the torpedo, yet the distance at which the attacked ship unlighted, as she would be in war time, could be seen, would not be more than some 1000 yards.

The sphere of action of the "Auto-mobile" type, such as the "Patrick," or "Nordenfelt," is, on the other hand, to all intents *unlimited*, as they can be worked from any point on shore, or afloat, and therefore the direction of their attack would be unknown to the enemy, for they could be launched from any point along the coast, being brought there overland, or by water; while they could also be towed out to sea under cover of the darkness, and attack a blockading fleet or ship from seaward; further, in combination with a submarine boat, their effectiveness would be infinitely increased, and this combination would unquestionably form a most deadly and sure mode of attack.

An advantage claimed for the Locomotive type.—One advantage the "Locomotive" has over the "Auto-mobile" is that its *motive power* is not destroyed on the torpedo being blown up, or lost, but this is entirely a financial question, and the slight extra cost of an exploded "Auto-mobile" ought not to be seriously treated as detrimental in considering its adoption, in view of its immense superiority over the "Locomotive" in the matter of applicability and sphere of action.

An effective Auto-mobile torpedo superior to the Brennan.—A torpedo of the "Auto-mobile" type, fulfilling the before-mentioned requirements, will assuredly prove in competitive trials, and on actual service, immeasurably superior to the "Brennan," lacking as the latter does the necessary freedom of action, a sufficient amount of directive movement and suitability, owing to its mode of operation.

Different methods of submergence considered.—The best method of providing a "controllable" torpedo with the power of running at a *fixed* depth below the surface is an important consideration, and doubtless each of the three systems, the "Sims-Edison" (the torpedo carried by its float), the "Nordenfelt" (the torpedo carrying its fins), and the "Whitehead" (automatic), will have its adherents. The "Whitehead" system, which has been adopted in a modified form in the "Brennan," has the advantages, supposing that uniformity of submergence be obtained, of enabling the torpedo to be run at a depth which brings the explosive charge, when in contact, well below the armoured belt of a battleship of the first class, and therefore renders its explosion most deadly, and this with the least loss of speed; in the

"Brennan" the steel mast by which its direction is controlled takes two knots off its speed; but if the "Brennan" had the degree of directive control common to the "Sims-Edison," "Patrick," and "Nordenfelt," two masts would be imperative, resulting in a loss of speed of four knots.

The "Sims-Edison" system, by which the torpedo is supported at a fixed depth from a float extending the whole length of the hull, or as in the "Patrick," some feet longer, and overhanging abaft, and the "Nordenfelt" system, by which the torpedo, in itself buoyant, supports two fins, enables these torpedoes to be submerged to any depth, but at the expense of their speed, owing to the increased resistance offered by every additional foot of depth of the float or fin supports, which must be of considerable structural strength; while, as in both of these systems, the submergence of the torpedo is the same whether at rest or moving ahead (which is not the case in the "Brennan"), a submergence of more than three or four feet would render the torpedo difficult to handle in launching. Both the *float* and *fin* system, however, enable an absolute uniformity of submergence during a run, which is not feasible with the "Whitehead" system, and if the submergence be only three feet, this secures immunity to hull from damage by gun fire, as well as the maximum effect of the explosive charge. As to the actual result of the explosion of 200 lbs. or 400 lbs. of dynamite in actual contact with a ship three feet below her water line, this is a question which yet remains to be settled.

The difference between the "Sims-Edison" and the "Nordenfelt" system of submergence is, that in the former case, the safety of the torpedo under fire is secured by providing the float with a very great excess of buoyancy over what is actually necessary to support it, so that the float may be struck repeatedly by the enemy's fire without rendering it incapable of supporting the torpedo; in the latter system, as the torpedo *carries* the two fins, if any portion or the whole of them be knocked away by the enemy's fire, the hull will still float, but at a somewhat less depth. In the "Nordenfelt" system the reserve buoyancy of the two fins is necessarily small compared with the "Sims-Edison" float, and together occasion less loss of speed, than does the long heavy float of the latter, while they also present a smaller target.

Exhaustive experiments will alone decide as to which of these three methods of submergence is the most suitable, but it must be remembered that the "Whitehead" system is common property, whilst each of the other systems is the subject of a patent.

The best method of propulsion considered.—The best method of propulsion for the "auto-mobile" controllable torpedo is also an important matter for consideration, and one that calls for exhaustive experiments, to demonstrate which of the systems now before the world is the most suitable for this particular class of weapon.

Steam, compressed air, carbonic acid gas and electricity have all been used as the motive power of these torpedoes, and taking into consideration the circumstances under which it is employed, the latter would seem to offer many advantages over the others, if only it is proved capable of enabling the torpedo to attain the requisite speed, and there is no reason to doubt its capabilities in this respect in view of the great improvements that have been effected in this form of propulsion since its adoption for this purpose by Mr. Nordenfelt who has, as it may be said, forced its development.

Advantages of electrical propulsion.—In the first instance a properly constructed electro-motor is undoubtedly the very simplest form of engine, having the minimum number of working parts, and may be used for a great number of runs (each being only of 8 to 10 minutes duration) without requiring to be even looked at. Secondly, the motive-power, electrical accumulators or secondary batteries, as used in the "Nordenfelt" torpedo, are perfectly acid tight, durable, highly efficient electrically, and can be used for two full power runs without being recharged; while they can be charged up after a run in one hour with the torpedo completely closed up.

Electrical propulsion will be found, for the particular purpose treated of, to be the cheapest, the safest, and the easiest to manipulate of any other method.

If it be permitted to use a motive power for an auto-mobile torpedo which shall last out three full power runs only, then a much greater power can be developed in a torpedo of similar dimensions by the employment of electricity, because the accumulators can then be very considerably reduced in weight; and on actual service it is rarely that such a weapon will be required to be used more than once; for practice and experimental purposes, the accumulators must needs possess the feature of durability in a high degree, and therefore the speed with such would be less than it is possible to attain with those kept in store and intended to be used on actual service only.

The accumulators retain their full charge for at least a fortnight after being fully charged up, and they can be kept in perfect condition for any length of time, if they are kept fully charged, or if they are stored in their boxes without acid before being formed; in the latter condition the torpedo could be prepared for service in from one to two days.

Their comparative merits for Naval Warfare.—The "Sims-Edison" and the "Lay-Haight" have been condemned as ship torpedoes by an American commission, for the following reasons, as set forth in their report:—

American objections.—1. One operator at least must be exposed, in order to watch the torpedo (Lay-Haight) when dropped into the water from a vessel under way, nor can the engines of the torpedo be safely started until it is clear of the ship. Even then a mistake in steering the torpedo might be fatal to the vessel herself, while a failure to start promptly might cause the torpedo to foul the ship's screw with disastrous results.

2. It would be necessary to have a reel of wire on board when firing from a vessel under way, or the torpedo would be unmanageable.

This would introduce a new source of accidents.

3. In the *mêlée* of battle the cables would be liable to displacement and fracture, and thus render the torpedo (Sims-Edison) uncontrollable, and therefore useless.

The above extracts have been taken from the Report of this Naval Commission on both the "Lay-Haight" and "Sims-Edison," as to their adaptability for naval warfare, as they apply specially to both classes of controllable torpedoes, the "locomotive" and the "automobile, and not to any particular type.

Validity of Objections with present Knowledge.—These objections are valid enough in the present want of real knowledge as to the capabilities of an "auto-mobile" controllable torpedo, whose manipulation from a ship in motion has been practically and carefully worked out.

Their use restricted to certain phases of Naval Warfare.—It may be admitted at the outset that in a general engagement between two fleets, such a weapon would probably be out of place, at least at the initial stage; and for the matter of that it is extremely unlikely that the "Whitehead" will be used under these circumstances; there are, however, certain conditions of naval warfare when the former class of torpedo would prove invaluable, and owing to its much greater length of range and its controllability, much superior to the latter weapon.

For instance, in an action between two ships, or where one ship is opposed to two ships, or even between four ships, in either combination of one to three, or two to two; again in the case of a ship disabled in a fleet action, unable to move ahead, or to steer, and therefore at the mercy of any of the enemy's sound vessels; then, again, as the torpedo armament of the so-called armed merchant steamers, they would be most useful; lastly, in special vessels this torpedo should give a good account of itself.

First Objection considered.—Then, considering the afore-mentioned first objection, there is no reason why the operator should not work the torpedo from a small conning tower, and directly the torpedo is started he would then only have to direct her, perfectly oblivious of the course of the ship; he would certainly run no greater risk than the captain of the ship, and an accident to the latter would certainly in these days be most serious, far more so than to the torpedo operator, whose place could be readily taken by any one capable of steering a boat.

As to the latter part of the first objection, there is no absolute necessity for carrying the torpedo in davits and so have to lower her into the water, and start her off with the ship under way; but suppose this plan to be adopted, it would be easy to put the rudder hard over, to whichever side she is lowered from, so as to give her a good sheer off before slipping the bow line.

It would, however, seem more reasonable to have the torpedoes (on actual service) towing, one on each quarter, from a short spar, which could be rigged in after the torpedoes are slipped.

The other Objections considered.—The last two objections deal with the question of the torpedo's cable, which apparently is as great a bugbear to this class of torpedo for this particular work, as the question of the supply of ammunition is to the machine-gun for field service, but a *controllable* torpedo for naval warfare possesses so many important advantages over any other kind, that this apparent difficulty will vanish as soon as ever this question is seriously considered.

It would seem very feasible, and by no means impracticable, to lead the torpedo cable (which is a very small one and readily sinks) through a small tube astern, so as to prevent it from fouling the ship's propeller, and as the reel of cable carried in the ship could be situated close to this tube below deck, there would be practically no fear of the cable on paying out getting in the way of the working of the ship or being damaged by the enemy's fire or otherwise; the last paragraph of the second objection would then become altogether invalid.

Question of Size.—A further objection has been raised on the score that the size of this class of torpedo renders them cumbersome and difficult to stow on board ship, but there is no reason why they should not be reduced in dimensions and weight from that adopted for those intended for harbour defence, if only a shorter extreme range (1500 to 2000 yards), a smaller explosive charge (100 to 150 lbs.), and a somewhat less rate of speed be admissible.

An "auto-mobile" controllable torpedo, with a 16-knot speed, a charge of 150 lbs. of dynamite, and an effective range of 1500 yards, would be a most valuable ship torpedo, and could be constructed without difficulty, and cheaply if only it were called for.

Fault of Official Experiments.—The official experiments that have been conducted up to the present with this class of torpedo, to prove their fitness for naval warfare, have seemingly been carried out with weapons designed for harbour defence, and without any attempt being made to fit them or their mode of manipulation for this special service, and therefore they have never yet been accorded a fair opportunity of demonstrating their effectiveness as ship torpedoes.

If any naval power desires to possess an "auto-mobile" controllable torpedo for ship work, it is only necessary for that power to declare, within reasonable limits, what is required from it in respect of speed, size, range, &c., for its desire to be fulfilled.

Methods of Carrying them.—These torpedoes, whether large or small ones, could be easily carried in davits or placed amidships; the explosive charge need not be put in until just before they are lowered into the water. In a time of peace they could be left in store, or if carried in a ship, and with all their gear out, two of them could be at need converted into an effective life-raft.

The Torpedo of the future.—The "locomotive" and "auto-mobile" of controllable torpedoes have been considered at some length, se one of these types, more probably the latter, promises to be orpedo of the future for both harbour defence and naval e.

settle this question once for all, it is not enough to experiment tely with any one type, but to pit the best of each class, the Mobile Uncontrollable (Whitehead, Howell), the Locomotive ollable (Sims-Edison, Brennan), and the Auto-Mobile Conole (Lay, Patrick, Nordenfelt), against each other under the impartial conditions.

SECTION IV.

TORPEDO BOATS.

CHAPTER I.

SURFACE TORPEDO BOATS.

CHAPTER II.

SUBMARINE TORPEDO BOATS.

CHAPTER I.

SURFACE TORPEDO BOATS.

1. Definition—2. Classification—3. The "Hunter" Class—4. The "Division" Class—5. Description of a Yarrow "Division" torpedo boat—6. The "Harbour" Class—7. Description of a Yarrow "Harbour" torpedo boat—8. The "Ship" class—9. Description of a Yarrow "Ship" torpedo boat—10. The rapid development of the torpedo boat—11. Qualifications—12. Considerations as to (*a*) Speed—(*b*) Handiness in manœuvring—(*c*) Coal endurance—(*d*) Seaworthiness—(*e*) Size, including habitability and suitability—(*f*) Armament (torpedo and gun)—(*g*) Vulnerability—13. Perfectness of torpedo boat compared to imperfectness of its present mode of attack—14. Suggested experiment to test degree of vulnerability of torpedo boat.

DEFINITION.—By a "surface torpedo" boat is meant a boat running on the surface of the water, and specially designed and constructed that it may have the various properties essential to a boat intended to be used solely for torpedo warfare.

The steam, or even the rowing boats of a war ship may of course be, and often are, utilised for this service, but they can only be considered as extempore, and not as torpedo boats proper.

Classification.—Torpedo boats may be divided into four classes, viz.:—

A. Hunters.
B. Division.
C. Harbour.
D. Ship.

"*Hunter*" *Class.*—The "Hunter" is, as its name implies, a special form of vessel created for the express purpose of hunting, and destroying hostile torpedo boats, and though, when its armament consists of light and machine guns only, it is not really a torpedo boat, yet as it is then a function of torpedo boat warfare, and as it is besides more generally provided with a torpedo, as well as a gun equipment, it may fairly be considered in this chapter.

When the "Hunter" is provided with a combined armament, it becomes very difficult to draw the line between it and the "Division" torpedo boat, as both call for the same qualifications, though the "Hunter" should of course be, at least, just superior to the latter in every way.

The qualifications of a "Hunter" are: (1) Speed; (2) Handiness; (3) Seaworthiness; (4) Structural strength; (5) Coal endurance; (6) Habitability; (7) Steadiness.

The fourth property of structural strength is a special feature of the "Hunter," and is intended to mean something over and above what every sea-going torpedo boat must perforce possess of this particular quality, because a "Hunter" must be capable of ramming, and charging down the "Division," and other classes of torpedo boats, and of standing the hard knocks inseparable from an action, with, perhaps, more than one of them.

It is impossible to fix any size of this class of war vessel, as up to this time no definite understanding has been arrived at as to the actual type of vessel best suited for this particular work of torpedo boat destruction; in fact, it would seem as though any boat, or even vessel capable of steaming from 18 knots upwards, provided she possesses a sufficient number of rapid-firing and machine guns, has now come to be looked upon as of the "Hunter" class.

The principal features of the vessels and boats specially designed for torpedo boat destruction are given in Table XVIII.

The Russian vessel of 600 tons has been included in this list, because of the exceptional number of the machine guns it is equipped with, but its work will be more probably that of a scout, or commerce destroyer, than as a "hunter."

The "Division" Class.—The "division" or "sea-going" class of torpedo boats includes those which by their size are capable of acting independently in torpedo warfare at sea, a certain number of which would be attached to each division of a fleet, hence their name.

These boats should possess the qualities of (1) High speed; (2) Handiness; (3) Coal endurance; (4) Habitableness; (5) Seaworthiness.

This class may be considered to range from 135 feet in length, and 100 tons in displacement upwards, but naval opinion points to even these large boats being relegated to the work of coast defence.

TABLE XVIII.

Year.	Length.	Displacement.	Speed.	Torpedo tubes.	Guns.	Built. In	Built. For	Remarks.
	feet.	tons.	knots					
1880	106	35·5	18	..	1 H. C. 12 cm. / 1 H. C. 35 mm.	France	Greece	
1885	150	220	20·8	4	3 1-inch N.M. guns	England	England	Diameter of circle 1¼ lengths.
1885	180	321	18	2	2 B.L.R. 3 H.M. "	France	France	Twin screws. Two steel decks. Belt of cellulose.
1885	180	350	22	3	1 B.L.R. {4 H.M. " / 2 N.M. "	England	Spain	Twin screws. Coal, and 1-inch steel over machinery.
1886	172	..	21	1	9 H. cannon	Germany	Austria	
1886	132	74	20	..	1 H. C. 14 cm.	France	France	
1886	..	600	20	..	24 M. guns	Russia	Russia	Single screw.
1887	200	450	19	4	1 B.L.R. {3 R.F. guns / 6 N.M. "	England	England	Twin screws.
1887	182	..	?	4	6 R. F. guns / 4 M. "	England	?	Twin screws, triple expansion engines.
1887	172	..	20	3	6 H. cannon	Germany	Denmark	5000 knots at 10 knots speed.
1887	175	..	22·5	3	6 H. "	Germany	"	6000 knots at 10 knots speed.
1888	182	..	?	4	6 R. P. guns / 3 M. "	England	?	Covered from stem to stern by steel superstructure.

N. *Nordenfelt.* H. *Hotchkiss.* M. *Machine.* R. F. *Rapid firing.*

A "Division" torpedo boat (No. 80), built in 1887 by Messrs. Yarrow and Co. for the British Government, a plan, elevation, and different sections of which is shown in Pl. LXXIII., will be here described as illustrating a very effective type of this class of boat.

The dimensions and particulars of the No. 80 are as follows:—

	ft.	in.
Length over all	135	0
Beam at water-line	14	0
Depth	9	2
Displacement with full bunkers and all stores complete . .	130 tons.	
Speed on official trial with 15 tons load, the average of 2 hours .	23 knots.	
Coal endurance at 10 knots	2700 "	
" Bunker capacity	25 tons.	

Turning Circles:

Going ahead to port .. 90 yards in diameter in 60 secs.

" " to starboard 110 " " " 65 "

Heel none.

Vibration. Trifling.

This boat is provided with one locomotive boiler, with over 2000 square feet of heating surface, and capable of supplying steam for 1600 I.H.P.: triple expansion engines to indicate up to 1600 H.P., with air, feed, and bilge pumps, worked direct off the crank shaft. Copper surface condenser, with ⅝-inch brass tubes; centrifugal circulating pump with independent engines; one large fan and engine for force draught; a double-acting donkey pump to pump out bilge, feed boiler, or act as a steam fire engine. The hull is subdivided by bulkheads into eleven watertight compartments, each having ample pumping apparatus in the shape of steam ejectors and hand pumps. Double steam steering gear is provided, so that either the bow and stern rudder may be worked independently of the other, and hand gear is also supplied in case an accident happens to the steam gear. The former is worked from the fore conning tower, where also is placed the engine room telegraph, and the apparatus for directing and discharging the *Whiteheads;* the hand gear is worked in a circular iron plated conning tower placed abaft, round which two torpedo tubes revolve for delivering a beam fire. There is also a torpedo tube built into the stem for end-on fire under the turtle deck forward. The gun armament consists of five quick-firing 3-pounder guns, three mounted on stands on the deck, and one on each conning tower. The accommodation for the officers and crew is more than usually roomy, the officers' cabin being aft, and the men's quarters forward, under the turtle deck. Tanks are provided containing 2 tons of drinking water, and also a Normandy condensing apparatus. A tank placed in the engine room, holding 1 ton of water, is supplied, to make up the waste from the boiler.

The "Harbour Class."—The "harbour" class of torpedo boats are intended to be used for harbour defence, and includes all those which are too large to be carried in ships, and too small for effectively fulfilling the duties of a "division" boat.

The qualifications of this class are (1) High speed; (2) Handiness; (3) Fair habitability; (4) Fair coal endurance; (5) Seaworthiness.

These torpedo boats range from 87 feet to 125 feet in length, and from 33 tons to 80 tons in displacement.

A "Harbour" torpedo boat, built also by Messrs. Yarrow and Co., for the Chinese Government in 1887, is shown in plan, elevation, and numerous sections, at Pl. LXXIV. This boat is a sister vessel to

No. 79, one of fifty-three built for the English Government in 1886–1887 (twenty-four by Messrs. Yarrow and Co., twenty-four by Messrs. Thornycroft and Co., and five by Mr. S. White, of Cowes), and this No. 79 proved on official trials to be some two knots faster than any of these boats built by the latter firms, while the Chinese sister boat succeeded in beating No. 79 by more than half a knot.

The dimensions and particulars of this Chinese boat are as follows:—

	ft. in.
Length over all	128 0
Beam at water line	13 3
Depth	8 3
Displacement	70 tons.
Speed on official trials with 10 tons load and stores complete, the average of 2 hours	22·88 knots.
Coal endurance	2000 knots at 11 knots per hour.
Bunker capacity	20 tons.

Turning Circle. Going ahead	to port ..	70 yards in diameter in 58 secs.
" "	to starboard	80 " " " " 72 "
" astern	to port	76 " " " " 90 "
" "	to starboard	40 " " " " 70 "

Heel. Practically none.
Vibration. Trifling.

This "Harbour" torpedo boat has the same kind of propelling and other machinery as the No. 80 "Division" boat before described, only on a somewhat smaller scale. She is provided with an Electric Search light, two bow torpedo tubes for end-on fire, and a single swivel tube on deck abaft for all round fire, and with four machine guns.

Though this Chinese boat has been described as of the "Harbour" class, she is quite capable of being utilised for sea-going purposes.

The "Ship" Class.—The "Ship" class of torpedo boats includes the largest-sized boat which can be conveniently carried on shipboard, and which may be readily lowered into and hoisted out of the water in ordinary weather.

The qualifications of this class are (1) Fair spe
(3) Strength.

These boats range from 64 feet in length, and 1
ment downwards.

A "ship" torpedo boat, of the most recent
(No. 50), built in 1887 by Messrs. Yarrow and C
Government, is shown in plan, elevation, and nu
Pl. LXXV.

The dimensions and particulars of this improve
predecessors, are as follows:—

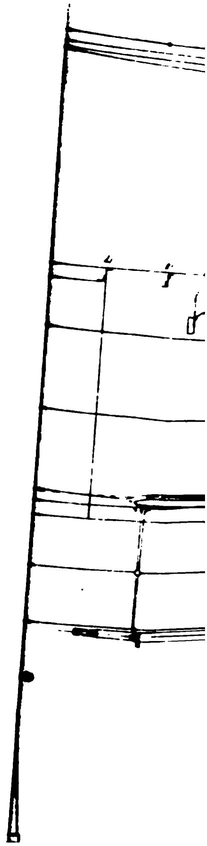
	N
Length over all	6(
Breadth at water line	8
Depth	5 ft
Freeboard	2 ft
Displacement	15
Lifting weight	11½
Speed on official trial, with 4 tons load, and stores complete.	17·04
Coal endurance at 10 knots	400
Bunker capacity	2

Turning Circles:

Going ahead to port .. 45 yards in diame
" " to starboard 55 " " "

This No. 50 is armed with one revolving torped
arranged as to be fired over either side and at any
sired to train it to, and also one Nordenfelt 2-barrel
forward; the torpedo tube may be replaced by a c
her armament may be entirely removed in peace ti
very useful for ordinary ship work, being capabl
fifty men. She has very fair accommodation, as
will hold twelve men and the one aft ten men.
a partially balanced rudder, and hand-steering ge
handiness enabling the extra complications of
be avoided. The boiler and the machinery is of
form.

Explanation of Mode of Classification.—The four
torpedo boats have here been divided has been reso
of preventing confusion in considering the various f
with the application of the "Hunter," "Divisio
"Ship" torpedo boat in actual war, and it must



l that each Naval Power possesses a certain number of boats of these classes, or that there is any recognised size for each ıless possibly for the latter one. At the present time the boat flotilla of every Power is conspicuous by the hetero- nature of its units, a fact that will prove beyond doubt point under the stress of a great naval war. A glance at IX., page 268, which shows the progressive development orpedo boat proper, will suffice to explain the above fact, ıonstrate the extreme difficulty of arriving at any rigid f classification.

Rapid Development of the Torpedo Boat.—The rapid develop- the torpedo boat, as set forth in Table XIX., is almost ınal in the case of any particular industry, more especially h has only been in operation for some fifteen years.

rapid rate of progress has been mainly due to the skill and se displayed by the two well-known torpedo boat builders, Yarrow and Thornycroft, and to the keen though friendly ngendered between them, and which has been all the keener they happen to be located on the same river (Thames) within, y be said, a stone's throw of each other.

ıout in any way disparaging the excellent work in the shape of boats turned out by the many other firms that may now be n this industry, notable among which are Messrs. Normand, of Schichau, of Germany, and White, of England, it must be l that the high state of perfection realised in the torpedo boat is greatly due to the two firms of Messrs. Thornycroft and whose earlier boats form the models on which those emanating er firms have been constructed.

these other firms have proved very apt pupils will be readily from a glance at Table XIX., and the enlarged sphere of on in this torpedo boat industry extending, as it now does, all ope, will unquestionably advance its future development at rapid rate, more especially in respect to the larger type of ater" and "Division" classes.

fications.—As the qualifications of each class of torpedo boat ·ilar, d mainly in degree, the author has considered lso to avoid unnecessary repetition, to discuss vith this special branch of naval warfare as a

TABLE XIX.

Date.	Length.	Beam.	Displacement.	Speed.	Coal Endurance at 10 Knots.	Armament. Torpedoes.	Armament. Guns.	Built. By.	Built. For.	Remarks.
	Ft. in.	Ft. in.	Tons.	Knots.					Government.	
1873	57 0	7 6	7½	14·97	..	1 towing . .	None . .	Thornycroft . .	Norwegian.	The first specially constructed torpedo boat.
1874	55 0	7 0	11·0	12·0	..	1 Spar . . .	,, . .	Yarrow	Argentine.	
1874	67 0	..	..	18·2	..	2 Spars . . .	,, . .	Thornycroft . . .	Austrian. French.	
1875	75 0	10 0	16·0	16 to 17	..	1 Spar . . .	,, . .	Yarrow	Dutch.	
1877	75 0	10 0	18·0	16½	..	1 ,, ...	,, . .	,, ...	Greek.	
1877	76 0	10 0	..	..	..	1 ,, ... 1 Whitehead .	,, . .	Thornycroft . . .	Dutch. Italian. .	First boat fitted with the Whitehead.
1877	76 0	8 2	23·0	18·0	..	1 Spar . . .	,, . .	Forges et Chantiers.	Spanish.	
1877	89 4	10 9	32·0	18·0	..	1 ,, ...	,, . .	,, ,, .	French.	
1877	119 8	11 9	44·0	18·0	..	1 Whitehead .	,, . .	,, ,, .	,,	
1877	87 6	10 10	32·4	18½	..	..	,, . .	,, . . .	British .	The *Lightning*.
1877	55 0	9 10	..	16·0	..	2 Spars . . .	,, . .	Schichau . . .	Russian.	
1878	60 6	10 9	..	17½	..	4 ,, ...	,, . .	,, ...	,,	
1878	86 0	11 0	30·0	21·93	..	1 Whitehead .	,, . .	Yarrow	British .	Fastest vessel then afloat.
1878	86 6	10 10	33·0	18·8	..	1 Spar . . .	,, . .	Normand . . .	French .	Mean of 3 hours.
1878	89 5	10 9	32·0	18·0	..	2 Whiteheads .	,, . .	Forges et Chantiers.	French .	Four built.
1879	63 0	..	10½	18·0	..	1 ,, .	,, . .	Thornycroft . . .	,,	
1879	87 0	10 6	32·4	20·0	..	2 ,, .	,, . .	,, ...	,,	
1879	59 6	..	8·0	16·0	..	..	,, . .	Herreschoff . . .	British .	Coil boiler. Screw and rudder placed underneath.
1879	89 5	10 9	32·0	18·0	..	2 Spars . . .	,, . .	Forges et Chantiers.	French.	Four built.
1879	106 8	11 8	29·0	18·0	..	2 Whiteheads .	,, . .	,, ,, .	Danish.	
1879	107 0	10 10	37·5	18·72	..	1 Bow tube under water.	,, . .	Normand . . .	French .	Mean of 3 hours.
1880	100 0	12 6	40·0	22·16	..	2 Whiteheads .	,, . .	Yarrow	Russian .	The *Batoum*.
1880	90 6	..	32½	21·75	..	2 ,, .	,, . .	Thornycroft . . .	British.	

1880	88	5	10	10	33·0	19·88	..	..	None	Normand	French.	
1880	88	5	10	10	33·5	20·75	..	1 Spar	„	„	French.	
1881	100	0	12	6	40·0	20·0	..	2 Whiteheads	„	Yarrow	Greek	Six built and delivered in 4½ months.
1881	100	0	12	6	40·0	22·46	..	2 „	„	„	Italian.	
1881	110	0	12	0	52·5	19·91	1200	2 „	„	Thornycroft	Danish.	
1881	89	6	10	9	32	18	..	1 „	„	Forges et Chantiers	French.	
1882	108	0	10	10	48·5	20·62	1650	2 „	„	Normand	„	28 lbs. of coal per knot at 10 knots speed.
1882	92	0	10	10	35·5	19·78	..	2 „	„	„	„	
1882	110	0	12	6	50·0	20·4	..	2 Whiteheads	„	Yarrow	Brazilian	Speed mean of 3 hours loaded trial.
1882	60	4	7	1	12	15	..	2 „	„	Forges et Chantiers	French	One also for Russia.
1882	121	4	12	0	71	18	..	2 „	„	„ „	Russian.	
1883	63	0	7	9	12½	17·27	..	1 „	„	„	British	Second class. Steam impulse.
1883	125	0	11	7	62·6	18·51	2800	2 bow tubes	„	Normand	Russia	The *Poti* class. 29·8 lbs. of coal per knot at 10 knots.
1883	50	0	9	0	10½	10·1	..	1 Spar	..	Yarrow	Roumania.	Torpedo launch, picket, or guard boat.
1883	122	0	15	8	..	20	3000	2 Whiteheads	2 Hotchkiss Q.F. guns	Schichau	German.	
1883	113	0	12	6	60·0	19·5	..	2 „	..	Thornycroft	Russian	The *Soukhoum*.
1884	63	0	7	9	13½	18·15	..	2 „	None	Yarrow	Brazilian	For the *Riachuelo*.
1884	100	0	..		35·0	21·4	..	..	..	Orlando Bros.	Italian.	
1884	108	0	10	11	49·3	20·3	1660	..	..	Normand	French	Whiteheads discharged by powder.
1884	122	0	15	8	..	20·5	3000	2 Whiteheads	2 Hotchkiss Q.F. guns	Schichau	German	Twenty-two built.
1884	135	0	13	10	82·0	22½	..	2 „	..	Yarrow	Austrian	The *Falke*. 3 hours mean speed 22½ knots.
1884	113	0	12	6	70·0	18·9	1500	2 „	..	„	British.	
1884	120	0	13	3	66·0	19·3	2000	2 „	..	„	German.	
1884	105	9	11	8	33	18	..	2 „	2 Nordenfelt Q.F. guns	Forges et Chantiers	Turkish.	

TABLE XIX.—*continued.*

Date.	Length.	Beam.	Displacement.	Speed.	Coal Endurance at 10 Knots.	Armament. Torpedoes.	Armament. Guns.	Built. By.	Built. For.	Remarks.
	Ft. in.	Ft. in.	Tons.	Knots.					Government.	
1885	125 0	13 0	..	20·9	2000	..	..	Thornycroft . . .	British.	
1885	124 0	15 8	..	21·53	2100	2 Whiteheads .	2 Hotchkiss Q.F. guns	Germania - Werft (Kiel) . .	Spanish .	Mean speed for 5 hours' trial, 19·86 knots; eight water-tight compartments.
1885	128 0	15 8	..	21	3500	2 „ .	2 Hotchkiss Q.F. guns	Schichau . . .	Italian.	
1885	86 0	11 8	..	19	1000	1 „ .	..	„ . . .	Chinese.	
1885	108 0	10 11	49·3	20·95	1260	..	..	Normand . . .	French .	Seven built.
1885	101 6	..	43·0	20·3	..	..	..	Forges et Chantieres	Turkish.	
1885	142 0	16 6	..	23	3500	2 Whiteheads .	2 Hotchkiss Q.F. guns	Schichau . . .	Chinese.	
1885	166 0	19 6	180·0	..	..	4 „ .	..	Yarrow	Japanese .	1-inch armour-plating; twin screws.
1885	140 0	14 0	100·0	25·1	..	4 „ .	..	„	Italian .	Twin screws.
1886	86 0	11 8	..	19	1000	1 „ .	..	Schichau . . .	Chinese.	
1886	124 0	11 2	53	20	..	2 „ .	„ . . .	Forges et Chantiers.	French .	Sixteen built.
1886	125 0	10 11	64·0	19·5	2600	2 Whiteheads .	2 Hotchkiss Q.F. guns	Normand . . .	Spanish .	The *Barcelo* class.
1886	131 0	10 11	62·0	19·52	2700	2 „	..	Normand . . .	French .	The *Balny* class.
1886	94 0	..	36·0	22·9	..	..	..	Herreschoff . . .	United States.	
1886	128 0	15 8	..	21	3500	2 Whiteheads .	2 Hotchkiss Q.F. guns	Schichau . . .	Italian .	Ten built.
1886	121 5	15 8	..	21·5	3000	2 „ .	„	„	German .	Thirty delivered.
1886	148 0	..	150·0	22	..	2 „ .	2 Q.F. guns	Thomson (Clyde) .	Russian .	Twin screws; circle in 73 seconds; 15½ knots going astern.
1886	125 0	15 0	75·0	18½ to 19	..	5 Whiteheads .	..	White	British .	Five boats.
1886	125 0	12 6	65·0	19½ to 20½	..	5 „	..	Thornycroft . . .	„ .	Twenty-four boats.

1886	125	0	13	0	70·0	19¼ to 22·4	..	5 Whiteheads .	..	Yarrow	British .	Twenty-four boats. (No. 79 type.)
1886	151	0	12	5½	96·0	19·7	3160	2 tubes . . .	2 Hotchkiss Q.F. guns	Normand . . .	Russian .	The *Sweaborg* class.
1886	45	0	..		3½	12	..	1 spar . . .	1 Nordenfelt 2-barrel gun	Thornycroft . . .	Brazilian .	River service; 13 inches draught.
1886	128	0	13	0	69·0	23·88	..	2 Schwartzkopffs	..	Yarrow	Chinese.	
1887	135	0	14	0	130·0	23·0	..	3 Whiteheads .	..	„	British .	No. 80.
1887	154	0	16	8	..	26·5	4000	3 „ .	2 Hotchkiss Q.F. guns	Shichau	Italian.	
1887	183	7	22	4	..	21·0	5000	3 „ .	6 „	„	German.	
1887	195	0	24	2	..	22·5	6000	1 „ .	„	„	Austrian.	
1887	147	6	14	6	98·76	24·9	..	2 tubes . . . 4 Whiteheads .	4·3-prs.	Thornycroft . . .	Spanish .	Speed on 2 hours run.
1887	125	7	11	2	56·0	21·0	..	2 Whiteheads .	None.	Forges et Chantiers.	Roumanian.	
1887	140	0	..		110·0	..	..	..	..	Turkish Dockyard .	..	
1887	135	0	14	0	103·0	24	..	2 Schwartzkopffs	..	Yarrow	Spanish .	The *Azor* and *Halcon*.
1887	60	0	8	6	15·0	17·03	..	1 Whitehead .	..	„	British .	New type of "Ship" torpedo boat. Ten boats ordered (1888).
1888	152	6	16	8	..	26·5	4000	3 „ .	2 Hotchkiss Q.F. guns	Schichau . . .	..	Building; speed estimated.
1888	138	0	14	6	99?	23·0?	..	8 Howells . .	2 Q.F. 6-prs.	Herreschoff . . .	United States .	Twin screws. Quadruple expansion. Speed estimated.
1888	139	5	14	8	103·0	20·5	..	3 Whiteheads .	2 cannons, 37 mm. .	Forges et Chantiers.	French.	
1888	130	0	13	6	..	22·5	..	3 „ .	..	Yarrow	British .	Six in hand.

whole, in preference to considering them in relation to each class separately.

These properties are as follows:—

a. Speed, including Durability of Engines and Boilers.
b. Handiness in manœuvring.
c. Coal endurance.
d. Sea-worthiness.
e. Size, including Habitability and Suitability.
f. Armament, including Torpedoes and Guns.
g. Vulnerability.

a. SPEED.

The factor of *speed* is, of course, one of the most important essentials in connection with every class of torpedo boat, whether engaged in the attack of a ship, or in hunting other torpedo boats, or for her own preservation.

The question is, however, now being seriously debated in naval circles, whether too much credit has not been, and is not now being, attached to this factor, to the possible detriment of some other equally important one, such as durability, for instance. Provided that all the other properties are satisfactorily secured, then the higher the speed, the more effective is the torpedo boat, but in the keen and extended competition that now exists in the construction of these craft, more particularly in the matter of speed—for that is the most effective factor in securing their sale and further orders—may it not be possible that, the efforts to turn out the fastest torpedo boat, or, as it is said, to break the record, results in the sacrifice of some other element of efficiency, which, however, may not be discovered until after continued use.

A striking proof of this is afforded by the great English torpedo boat race of May, 1887, when twenty-two of these craft were set to race against one another over a distance of 100 miles, and that seven of them were placed *hors de combat* through machinery accidents, and one through the loss of a blade of her propeller; the flotilla consisted of four Yarrow, three White, and fifteen Thornycroft boats, and the eight disabled ones were all Thornycrofts; a Yarrow boat came in first, beating a White boat by the small margin of five seconds, a Thornycroft following some five minutes after. It has been said that these numerous accidents were, in some measure, caused by the inefficiency of their engine-room staffs, but, putting on one side, the curious coincidence, if such were the case, of the Thornycrofts being the only unlucky boats in this respect, surely it cannot be intended that torpedo boats should only be manipulated by engineer specialists, for, if so, their utility in a time of war becomes utterly destroyed.

In considering this question of high speed, it must be remembered that a torpedo boat in actual service will not be worked by the specially trained engineers and stokers belonging to the firm producing it, and therefore the speed attained on her builder's official trial can never be expected from her under ordinary service conditions; thus the true relative value of any two torpedo boats in the matter of speed is as the respective speeds attained by them when worked by their service crews.

It is quite possible that A may build a torpedo boat faster by 2 knots than one turned out by B, as demonstrated at the official trial, causing the former to be awarded any amount of commendation at the hands of the press, and yet that the B boat should show as high, or a higher, turn of speed than that of A, when run under ordinary service conditions. It is, of course, only right that A should have all the *kudos* attached to turning out the fastest boat, because the speed obtained on the official (builder's) trial is a proof of what the boat is actually capable of in the hands of specialists, but it would seem more sensible and more practical to judge as to the useful capability of any particular torpedo boat from the results of one or more full-speed runs with her ordinary trained, but not specialist, staff in the engine room, and without the aid of extra special advantages of picked coal, and a barrel of beer in the stokehold.

It is extremely doubtful if an average speed of 20 knots per hour for a run of some two or three hours' duration could be obtained at any given time from all of the larger type of torpedo boats of recent construction, with their regular crews, and even more so after a spell at sea of a week or so with a proportion of bad weather.

The "Hunter" class, when on their special mission of torpedo boat capture or destruction, of course require to be capable of realising under similar conditions a higher rate of speed than their victims, but if official trials are to be accepted as the measure of a boat's proficiency in this matter of speed, then the general run of the present

"Hunters" certainly lack this requirement; however, as they are of greater tonnage, and therefore have more space for their engines and boilers, and may, besides, have greater strength of machinery, the "Hunter" class would probably prove able to steam at a faster rate than most torpedo boats under ordinary conditions on actual service. In the "Division" class, high speed is an essential qualification, firstly, because it would enable the torpedo boat to be, as it were, here, there, and everywhere, and the higher her speed, the greater her power for rapid and frequent changes of position from place to place: secondly, because it would afford her the necessary means for rapidly overhauling any hostile man of war she might be in chase of, possessing the ordinary rate of speed of such vessels, and the higher the speed possessed by the torpedo boat, the greater the chance of her meeting with hostile ships of a much less speed: thirdly, this is a most necessary element of defensive or aggressive tactics when engaged with a hostile torpedo boat, because here again the higher her speed, the more likely she is to meet with hostile ones inferior to her in this respect, and any advantage in speed means practically the command of the position, whether in defence or attack, with other things equal: fourthly, because it would permit of the torpedo boat passing over in the shortest time, and therefore with the greater safety, the space between the point where she first comes within effective range of the quick-firing and machine guns of the attacked vessel, and the point where she can deliver her blow (the Whitehead) with a fair chance of success: fifthly, because she can also retire beyond this dangerous space, after delivering her blow, in the shortest time.

In a daylight attack, looking to the comparatively large target offered by the boats of the present "Division" class, this danger space would extend *over* some 900 to 700 yards, *i.e.* from 1200 yards to 500 yards, or 300 yards *from* the vessel against which the attack is being delivered when the torpedo boat is armed with the "Whitehead" *uncontrollable* torpedo; this torpedo cannot be relied on beyond 500 yards' range, which should be reduced to at least 300 yards to insure any great certainty of its hitting. While in the case of a night attack in the face of the electric search light, the torpedo boat would probably come within range of the enemy's gun-fire at some 800 yards' distance, representing a danger space of 500 yards.

The following Table shows the times that would be occupied by a torpedo boat in passing over these spaces, 900, 700, and 500 yards, at speeds varying between 26 and 20 knots.

TABLE XX.

Speed in Knots.	26	25	24	23	22	21	20
DANGER SPACE.	TIME OCCUPIED.						
	secs.	secs.	secs.	secs.	secs.	secs.	secs.
900 yards	61·2	64·2	66·0	69·2	72·3	75·8	79·5
700 yards	47·5	49·4	51·6	53·1	56·13	58·8	61·7
500 yards	34·0	35·6	37·0	38·4	40·2	42·1	44·5

Now, allowing a rate of fire from the quick-firing and machine guns of a first-class man of war of 1000 shots per minute, then Table XXI. shows the number of shots that the torpedo boat would be subjected to whilst passing over these distances at these rates of speed.

TABLE XXI.

Speed in Knots.	26	25	24	23	22	21	20
DANGER SPACE.	NUMBER OF SHOTS.						
900 yards	1022	1072	1102	1156	1207	1266	1327
700 yards	793	825	862	887	936	982	1030
500 yards	568	584	618	641	671	703	738

Then, carrying this consideration still further, and allowing 8 per cent. of hits in a daylight attack, and 3 per cent. in a night attack, the results in Table XXII. are obtained.

TABLE XXII.

Speed in Knots.	26	25	24	23	22	21	20
DANGER SPACE.	NUMBER OF HITS AT 8 PER CENT. OF SHOTS.						
900 yards	81	85	88	92	96	100	105
700 yards	63	66	68	70	74	78	82
500 yards	44	46	48	51	53	56	61
	NUMBER OF HITS AT 3 PER CENT. OF SHOTS.						
900 yards	30	32	33	34	36	37	39
700 yards	23	24	25	26	27	29	31
500 yards	16	17	18	19	20	21	23

The relative chances of a torpedo boat receiving a vital shot while passing over these danger spaces of 900, 700, and 500 yards, at speeds varying from 26 to 20 knots, both in a day and in a night attack, will be readily obtained from the foregoing Tables, and from which may be gathered the importance, or otherwise, attaching to the power of very high speeds for a short time under these conditions, and for this special service. For instance, in daylight for a danger space of 900 yards, the ratio between a 26-knot and a 20-knot torpedo boat would be as 1 to 1·296, and similarly at night time for a danger space of 500 yards it would be as 1 to 1·437. It has, of course, to be conceded that the accuracy of the "Whitehead" is not impaired by discharging it from a torpedo boat proceeding at the higher speeds.

The foregoing considerations as to speed in connection with the "Division" class applies also to all classes of torpedo boats when employed in making an attack on an enemy's ship, but each class has besides, other special considerations.

The "Division" torpedo boat, for instance, being intended to accompany a fleet at sea, must therefore be capable of maintaining with comparative ease the highest rate of speed possible to the fleet, *i.e.* the full speed of the slowest ship, which may be set down at from 12 to 16 knots, depending upon the type of ships composing the fleet. Further, as the "Division" class may be called upon to act as despatch boats, it must be able to steam economically at a high rate of speed, say at least 18 knots, for a considerable distance, depending upon the amount of coal carried, and the consumption, without causing undue wear and tear to the machinery, or over-taxing the energies of the engine room staff to keep steam.

The "Harbour" class should similarly possess this latter feature of the "Division" class when making long passages from one port to another, with also the power of proceeding at full speed for comparatively short runs when their services are urgently needed at a port near to their station.

The "Ship" class would only need high speed for the purposes of making an attack.

In connection with this question of speed, durability is intimately interwoven, that is to say, the capabilities of the machinery of a torpedo boat to withstand the wear and tear of constantly being driven at high pressure for periods extending over several months, as would most assuredly occur in actual war; in addition there has to be considered the fatal consequences that might ensue from the break down of the machinery of a torpedo boat forming one of a division executing an attack at night-time; so that too much importance cannot be placed on the strength and nature of the engines and boilers of a torpedo boat, even if this matter be insisted upon at the cost of the loss of as much as one knot in speed (official trial).

b. HANDINESS IN MANŒUVRING.

All the torpedo boat classes require to have this property of handiness to the utmost perfection, whether in attack or in defence, that is to say, the power of rapidly answering their helm, and of making a complete circle of the smallest diameter possible when running at full speed.

The "White" system of cutting away the dead wood aft, now generally adopted, improved the turning powers of his torpedo boats to a remarkable extent, earning for them the effective title of *turn-about* boats.

The "Yarrow" system of bow and stern rudders has also proved very effective in reducing the turning diameters of those boats, and the provision of a bow rudder increases the manœuvring powers when going astern; this bow rudder is a balanced one, and is arranged to be let down under the boat, or drawn up into a well, when not required; and it can be worked either separately, or in combination with the stern rudder.

At the present time, torpedo boats of 120 feet and upwards may be generally taken as capable of turning a complete circle in from fifty-five to sixty seconds, and of a diameter somewhat less than twice their lengths.

The adoption of twin screws in some of the more recently constructed "Division" torpedo boats, adds additional manœuvring powers, as well as halving the chances of a total disabling of the boat through damage to the machinery, there being two sets of engines instead of one in the case of a single screw, and either of them is capable of driving the boat at a fair speed should the other one become disabled.

There is one point in connection with the manœuvring of torpedo boats upon the efficiency of which at all times so much depends, and that is the protection of the steering gear, and a ready method of replacing steam by hand gear, in case of the former being disabled.

Too much attention cannot be paid to this matter, and it might with advantage be insisted upon that there should be duplication of the steam steering apparatus, either of which should be capable of being thrown into and out of gear in the shortest possible time; for an accident rendering a torpedo boat incapable of being manœuvred even for a quarter of an hour, would, in an attack on a ship, be a very serious matter, and in an engagement with another similar boat would most decidedly bring about her capture or destruction.

c. Coal Endurance.

This property of coal endurance, which means the capability of steaming long distances at a fair rate of speed, and is measured by the capacity of the coal bunkers, and the economy of working of the engines, is an essential condition for the "Hunter" and "Division" classes, but is not so necessary in the case of the "Harbour" class, while it is only possible to secure a small coal endurance for the "Ship" class, owing to the necessity of their small dimensions.

The "Harbour" torpedo boat being, as its name implies, intended for harbour defence, would always be in position to replenish her coal bunkers, while the "Ship" class would be dependent for their coal supply on the vessels to which they are attached, and would, besides, never be called upon to act at any great distance from their base.

Both the "Hunter" and the "Division" torpedo boat would usually be attached to a fleet, accompanying which it is now proposed there should always be one or more coal depôt vessels, from which these torpedo boats, as well as the ships, could draw fresh supplies of coal, but a "Hunter" or a "Division" boat might at any time be called upon to act independently away from the fleet, on despatch service, and such like, when a great coal endurance would prove an inestimable feature.

The torpedo boats of these classes of recent construction are capable of steaming from 2000 knots to 4000 knots, at the rate of some 10 to 11 knots per hour.

d. SEAWORTHINESS.

So far as the mere capability of keeping the sea in heavy weather, the "Hunter," "Division," and "Harbour," torpedo boats have proved the possession of this quality of seaworthiness in a remarkable degree, in fact, instances are on record of a torpedo boat keeping the sea when large ships have been forced to seek shelter.

But the "Hunter" and "Division" class require to be somewhat more than mere casks in the water tossed to and fro, they must be capable of affording a certain amount of steadiness at sea, even in a strong breeze of wind, especially when attacking to windward, so as to render it feasible to discharge their "Whiteheads," and fire their machine guns with some degree of accuracy.

In October, 1886, in an attack made on the *Richelieu* by a torpedo boat (108 feet long, and 45 tons displacement), it was found impossible to discharge the "Whitehead" with the boat head to sea, the bow tubes being constantly submerged, and she had finally to be given an opportunity of firing her torpedo to leeward; and though this was done at a distance of only 200 yards, at the *Richelieu* broadside on, representing a target of 322 feet in length, the torpedo missed, owing to the boat surging at the moment of firing.

Further, this question of seaworthiness is intimately connected with that of the comfort of the crew, for where it is necessary to batten down a torpedo boat on every occasion of a breeze of wind, the life of the crew must become most harassing and most harmful, seriously affecting her efficiency.

e. SIZE (INCLUDING HABITABILITY AND SUITABILITY).

This property of a torpedo boat has a different application for each class, but, except in the case of those of the "Ship" class, which must, from the nature of their service, be limited, there exists no definite dimensions for either of the other classes.

The "Hunter" and the "Division" torpedo boat must of necessity be of large dimensions to enable them to fulfil the requirements of seaworthiness, coal endurance, and habitability essential to such craft, and also to permit of their being equipped with a sufficiently powerful torpedo and light gun armament with all the concomitants attendant thereon, such as men to manipulate them, spare torpedoes, air-compressing machinery, and ammunition. The only limit to their largeness being the question of expense, and of the increased target offered to the guns of the defence; and it is a question whether in the most recent "Division" torpedo boats all the increased advantages of better accommodation for the crew, a somewhat steadier platform in a seaway, slightly higher speed, and somewhat more coal endurance will not, in actual war, be found to be more than compensated for by the increased target they offer.

It would seem as though the 135-foot, 130-ton boat, described at page 263, is large enough to fulfil satisfactorily *all* the conditions essential to an useful and effective "Division" torpedo boat.

Of course where the "Hunter" is intended to be utilised solely as a torpedo boat destroyer, and therefore not equipped with any torpedo armament, this consideration as to the size of the target she offers does not apply in the same degree; but in this case it would seem more practical and more economical to combine in such a craft the capabilities of a commerce as well as torpedo boat destroyer, and to make her very much larger, even up to 400 or 500 tons, instead of restricting her to dimensions only somewhat larger than that of the "Division" class.

It must always be remembered that the longer the boat the slower the manœuvring power, as this is an important feature in the catching and destruction of torpedo boats.

In dealing with this property in connection with the "Harbour" class there has to be considered the depth of water of the coast ports or rivers they are to defend, and the nature of their service, *i.e.* whether they are to be of such a size as to be capable of being conveyed from port to port by rail, or whether they are intended to proceed to and from these places by water.

In regard to the question of "Harbour" torpedo boats capable of being transported by rail, the Russians in 1877 required a *hundred* of such craft, and after careful consideration they adopted a type of boat of the following dimensions:

Length 75 ft.; beam 10 ft.; maximum draught 5 ft. 4 in.; displacement 18 tons; speed 18 knots.

Such a boat would be found a sufficiently good sea boat, and possessing all that would be necessary in the matter of accommodation, coal endurance, handiness, and speed for the work of harbour defence.

This matter of transporting the "Harbour" torpedo boats by rail is a most important one, and requires careful consideration, as it will be impossible for financial reasons to provide torpedo boats for all the unimportant harbours and river mouths, but which might be approached by an enemy's ship for the purpose of pillage; and under such circumstances it would be of considerable advantage to possess the means of being able to bring by rail one or more torpedo boats from other ports in the quickest time possible.

As to the most suitable size of the "Harbour" torpedo boat intended to go from port to port by water, this is a matter of opinion, but looking to all the requirements of such a craft, a 110-foot, 50-ton boat of 20 knots speed would appear to amply fulfil them, and certainly the limit of size would seem to be reached in the 120-foot, 66-ton boat of 6½ feet draught of water.

The "Ship" class which have to be carried in a ship, either inboard, or hung at davits have perforce to be limited in size, and the only consideration in regard to these craft is to construct them of such a shape and dimensions as to secure decent accommodation, strength of hull, and fair speed, and these features seem to have been secured in the recent Yarrow type of "Ship" or "Second Class" torpedo boat before described.

Habitability, the extent of the accommodation provided for the officers and crew, more especially of the engine-room staff, is a very important essential in connection with the sea going "Hunters," and "Division" torpedo boats, as practical experience has demonstrated that the work in an ordinary torpedo boat constantly under way for even a few days is most harassing and fatiguing.

f. Armament (Torpedo and Gun).

The armament of a torpedo boat may consist of both torpedoes and quick-firing or machine guns, but all of them are however provided with the former, and which is of the greater consequence, as the *effectiveness of the torpedo is the actual measure of the power of the torpedo boat.*

All that money, skill, and the keenest competition can do to secure perfection in any material appertaining to the art of naval warfare has been expended in no stinted manner on the torpedo boat, and though actual perfection may not have been achieved, yet this type of war vessel has been unquestionably brought to within a measurable degree of it, at any rate in so far as such is capable with steam propulsion. But though both money and skill have also been lavished in an even greater degree in striving to perfect the torpedo boat's weapon of offence, the "Whitehead," yet the latter falls lamentably short of the former in effectiveness. In plain language, the aggressive power of the torpedo boat is totally inadequate to its immense capabilities, which is a matter that appears to have been entirely overlooked in the race for "record breaking" with torpedo boats.

The torpedo armament of all classes of torpedo boats consists of one or more "Whiteheads," depending on the size of the boat, and the form of attack preferred in different navies. Formerly the torpedoes were fired from one or two bow tubes only, but recently considerable favour has been accorded to the system of broadside tubes, two sets of the latter being usually provided with one or two bow tubes, and occasionally with a stern tube also.

The alleged inaccuracy of the "Whitehead" when fired from a bow tube at high speeds, and also the difficulty of providing a suitable shape to the bows where two of these end-on tubes are placed abreast of one another, has been partly the reason for the adoption of the broadside discharge, but this latter form is also considered to promote an increased efficiency in making an attack.

In delivering an end-on attack, the torpedo boat must either be stopped and driven astern at the moment of discharging its "Whitehead," *i.e.* when it has reached to within 500 yards distance from the ship, or the helm must be put hard over if full speed be maintained, at the instant of firing, in which case the boat would of necessity be brought broadside on to the ship at dangerously close quarters. But with broadside firing the boat need never be brought nearer to the ship than the range at which an accurate shot with the "Whitehead" is feasible, as she would at the moment of firing be on the point of turning away from the ship; with the Yarrow system of double tubes, they being set at a slightly divergent angle and fired simultaneously, the chances of a hit are materially increased.

The bow, broadside, and stern discharge of the "Whitehead" is, however, entirely a tactical consideration which can only be settled by careful and systematic experiments based as far as is feasible on what may be expected to happen in real warfare; but surely it might, and ought to, be settled once for all as to which of these methods of "Whitehead" discharge from a torpedo boat when proceeding at a high rate of speed affords to that weapon its greatest accuracy.

Perfectness of Torpedo Boat compared to Imperfectness of its Present Mode of Attack.—It is now possible to obtain a torpedo boat having a speed of from 25 to 28 knots per hour, a coal endurance represented by a run of 5000 knots at the rate of 10 knots per hour, and capable of turning a complete circle at full speed in about a minute, and of a diameter twice the boat's length, but her mode of attack is of such a nature that she must be brought to within 500 yards of a hostile ship to enable her to deliver her blow (Whitehead) with even a hope of success. Now in these days of quick-firing 40-pr., 6-pr., and 3-pr. guns, the Nordenfelt 4-barrel 1-in. machine gun, and of electric search lights, and also because of the comparatively large target offered by such a boat, this means that her chances of coming out of the action unharmed will be very few, while the chances of her being severely damaged will be very great, and even her destruction very possible, either before or after she has fired her torpedoes.

Then, putting on one side the proverbial uncertainty of the "Whitehead" attack, there is further the apparently insurmountable obstacle to the "Whitehead" success in the shape of net defences, judging from the 1887 *Resistance* experiments, so that the question of torpedo boat warfare stands thus: *ten* to *twenty thousand pounds* are laid out in a vessel which is equipped with a means of offence necessitating that costly vessel being brought into dangerous proximity to the enemy's ship to enable it to deliver its blow with a faint chance of success, but which blow cannot penetrate a form of defence (nets) which every ship is now provided with, and which she may use on nearly all occasions.

It would then seem a matter for serious and immediate consideration to seek for some form of torpedo which shall give to the almost perfect torpedo boat of the present day a power of aggressive action more capable, than the present weapons, of bringing all the excellent qualities of such a vessel into play, and at the same time without obliging the torpedo boat, whilst delivering its attack, to become dangerously exposed to the enemy's fire.

The Uncontrollable type of torpedo has hitherto been considered as the only kind available for use in torpedo boats, and so long as this impression holds good, so long will the "Whitehead" retain its place, because it is the best of its class; but is it not possible to utilise a *Controllable* torpedo for this purpose; such an one could be constructed capable of being carried in a torpedo boat, and which would have three to four times the range, and two to three times the destructive power of the "Whitehead," a speed sufficient for all practical purposes, and as compared with the latter absolute certainty of hitting.

The controlling link between the boat and the torpedo, an electrical cable of very small diameter (0·25 inch), seems even now to be looked upon as an insuperable objection to this class of torpedo for boat equipments, but as yet no earnest effort has been made to prove whether this is a real or only an imaginary defect.

Considering how immensely a *controllable* torpedo would add to the efficiency of the torpedo boat as a means of offence, this system warrants at least a fair trial.

Gun Armament.—The gun armament of a torpedo boat is intended solely for its defence, when attacked by other similar craft, or by guard boats, or the "Hunter," but even in this matter considerable difference of opinion exists, as to the nature of this equipment, whether it should be rifle calibre, or 1-inch machine guns, or light quick-firing guns, or a combination thereof, and a settlement of this question will probably never be arrived at until an actual engagement has taken place between the torpedo boats of two European powers.

g. Vulnerability.

The actual vulnerability of any torpedo boat has never yet been determined, as this factor applies not only to the vessel, that is to say to the possibility of sinking it, or so damaging its propelling and steering machinery by gun fire as to disable it, but also to its torpedo equipment, and its officers and crew, particularly the commander and engineer.

A torpedo boat (*Whitehead*) attack may be foiled through many causes, among which the following are the more important ones: (1) it may be sunk by the penetration of shot and shell below the water; (2) it may be rendered practically unmanageable by one or more of its end compartments being pierced and filled with water; (3) it may be destroyed by a shot or shell penetrating its boiler; (4) it may be placed *hors de combat* by a shell exploding in its engine room, or by a shot striking an important part of its propelling machinery; (5) it may be rendered unmanageable by its steering gear, or engine being disabled by the gun fire; (6) it may be seriously damaged and very possibly destroyed by a shot or shell penetrating the air (highly compressed) chamber or the charge chamber of one of its torpedoes; (7) and the attack would probably be for the time foiled by the wounding or killing of its commander, or its engineer, especially the former.

The larger torpedo boats of more recent construction are provided with a very effective means of protection for their boilers and machinery by the coal bunkers (when full), which are carried round the sides and fore end of these parts; they are also divided up into a number of water-tight compartments, and are provided with ample pumping powers, and steam ejection.

Every means is thus supplied to prevent such a catastrophe as the actual sinking of a torpedo boat by the penetration of shot or shell; but what would be the result of the explosion, say of a 3-pr. shell on penetrating below the water line, is so far a matter of conjecture. An important question in connection with this matter is the provision or otherwise of man-holes, or doors in the bulkheads of the various water-tight compartments for the purpose of access from one to another, and it would certainly seem advisable to prohibit such, as there is always a chance of one or the other being left open, or at least not efficiently closed, while it is easy in such comparatively small vessels to go over all from one compartment to another by means of ladders. Messrs. Yarrow and Co. have now abandoned water-tight doors in bulkheads.

As to the effect of gun fire on the torpedo (*Whitehead*) equipment of these craft, though this has never yet been properly experimented upon, it would very likely be attended with disastrous results, and by the recent adoption of the above-deck tubes for broadside firing this source of danger is further intensified.

The wounding or killing of the commander just previous to the supreme moment of the attack, when the effective position has been reached for the discharge of the "Whitehead," would most assuredly bring about a failure, and very possibly cause the destruction of the torpedo boat, as it would be seriously exposed to the enemy's gun fire during the interim between this catastrophe and the next in command picking up the, for the time, lost thread of the operation.

Conning towers capable of resisting the lighter guns are certainly provided for the commander from which place of safety to direct the attack, but the position affords but a very circumscribed view, more particularly at night time, and therefore it is extremely probable that in nine cases out of ten he would prefer, if he be not actually obliged, to take up a position outside the conning tower, even though he be thereby exposed to the enemy's fire.

Suggested Experiment to test Degree of Vulnerability of Torpedo Boat.—This factor of vulnerability is so important that it would be worth making a more realistic experiment to decide this question than has ever yet been attempted, somewhat after the following plan: *

"Let a torpedo-boat be fitted with a length of cable (say one mile) reeled up in a manner similar to that adopted in controllable torpedoes, and also provided with electric gear for steering her, and starting and stopping her engines, and then, having placed dummy figures representing the officers and crew in their proper places, and the torpedo boat fully equipped, let her be run, as in making an end-on attack, against a ship provided with her proper complement of guns of all descriptions, and which vessel should open fire with the boat 1200 yards distant, and cease fire when she has reached her firing position, 500 yards distant from the ship.

"A second test might similarly be made with the torpedo boat with two or four movable above-deck tubes and one or two conning towers, the boat being steered as would actually be done in making an attack with a torpedo boat thus fitted; and, lastly, a similar series of experiments might be made at night-time.

"The above is merely put forward as a rough sketch of a far more realistic experiment than has yet been attempted; the details would, of course, have to be carefully worked out, but there seem no unreasonable difficulties in the way. As the ship's gunners would not

* Extract from an article on 'Torpedo Boat Warfare' by the author, published in *The Army and Navy Magazine* for March, 1885.

have the actual fear of their vessel being torpedoed and sunk, and as the attack would only be made with one instead of a number of boats, they would possibly fire with greater coolness and accuracy, and therefore it might be advisable to somewhat reduce the number of guns brought into action."

Though such an experiment might turn out to be a costly one, by causing the destruction of a torpedo boat, yet it might be most efficacious in providing practical data for securing to the future torpedo boat invulnerability in a higher degree than such craft now possess.

CHAPTER II.

SUBMARINE TORPEDO BOATS.

1. Definition—2. Erroneous view of the function of the Property of Submergence—3. Retrospective—4. Causes of naval dislike to the use of Submarine Boats—5. Description of the "Tuck"—6. The "Goubet"—7. The "Holland"—8. The "Nautilus"—9. The "Nordenfelt"—10. The Property of Submergence too prominently put forward—11. The question of danger in a submerged run—12. The objection of uncanniness—13. The want of a proper Torpedo Armament—14. The want of adequate size and strength—15. The Method of Propulsion—16. Insufficiency of speed—17. The Method of Submersion.

DEFINITION.—Torpedo boats which, by reason of a special system of construction, are capable of being propelled at considerable depths below the surface of the water are usually termed "submarine" torpedo boats; as however this is not the normal state of these vessels, they should rather be designated as "submersible" torpedo boats.

Certain vessels of this class are also sometimes termed "Diving" boats, when their submersion is effected by diving as opposed to those which achieve this result by being either sunk, or drawn horizontally, beneath the surface.

Erroneous view of the Function of the Property of Submergence.—It has hitherto been commonly supposed that this class of torpedo vessel is always intended to do its work *below* the surface of the water, an erroneous notion that has done more than anything else to create an adverse feeling (even still held by some) as to the general adoption of such craft, but it cannot be too strongly pointed out that the property of submergence possessed by a *submersible* torpedo boat only requires, and is only intended, to be exercised under exceptional circumstances.

The latest type of submersible boat, the "Nordenfelt," possesses the option of being run under either of four different conditions, viz.: (1) on the surface; (2) partially submerged with the turrets above; (3) further submerged with only the glass dome showing; (4) and wholly submerged; and it will be found that on actual service the principal portion of her work will be performed under the first and third conditions.

Retrospective.—The idea of a submarine or submersible boat for war purposes has been before the world for over 200 years, and during this long period of time almost every conceivable method of submersion and propulsion has been proposed or actually tried, but so far inventors have failed to secure the favourable notice of naval men; in a half-hearted manner, and apparently with the sole purpose of, here and there, satisfying the persistency of an inventor one or other of the naval powers has certainly carried out experiments with a submersible boat, or rather has permitted its inventor to show the capabilities of his particular vessel, but it is only within the last year or so that the Naval Powers seem to have awakened to the fact that a *submersible* torpedo boat is a practical possibility, and worthy of some real consideration.

In the American civil war, a quarter of a century since, a submarine boat was certainly effectual in sinking a ship, in which operation she was also lost; but this can only be looked upon as a species of forlorn hope, more especially as three crews had previously been lost in this same boat during her initial experiments; while Russia is known to be in the possession of a number of "Goubet" submarine boats, but these are too small and too slow to come within the category of submarine boats useful for torpedo purposes.

The third-rate Naval Powers of Greece and Turkey by their purchase of "Nordenfelts" may thus fairly claim to be leading the way to the general adoption of submersible *torpedo* boats, for, whatever may be urged against the employment of this class of war vessel, they will as surely be accepted at no distant time, as have been machine guns and magazine rifles, against the introduction of which weapons a powerful opposition has ever been raised.

Causes of Naval Dislike to the Use of Submarine Boats.—The reasons for the dislike, or rather distrust, hitherto displayed by naval men in regard to the employment of submersible torpedo boats are not difficult to understand for any one who has studied the history of this type of vessel, and may be classed as follows:

1. The fact of their being submarine.
2. The want of a proper armament.
3. The want of adequate size and strength.
4. The method of propulsion.
5. The lack of speed.
6. The method of submersion.

In considering the foregoing reasons, to which may be attributed the non-adoption of submersible torpedo boats, the qualities conducive to an effective vessel of this type may at the same time be discussed, but before however entering on this matter it will be best to briefly describe the general features of the more modern types of this class of vessel, among which are included the "Tuck," the "Goubet," the "Holland," the "Nautilus," and the "Nordenfelt."

Description of the "Tuck."—This submarine boat is the design of Mr. J. S. Tuck, of the United States.

The submarine monitor is an iron, cigar-shaped boat about 30 ft. long and 6 ft. in diameter. At the stern, in addition to an ordinary propeller and rudder, there is a horizontal rudder. Beneath the middle of the boat is a second propeller which acts vertically. On the top of the boat is an iron hatch, two small round holes, and a hollow iron pipe about 20 ft. long which lies on the deck. These and one or two small holes in the bottom are all that can be seen from the outside.

In the interior of the boat, in the bow, are placed the electric storage batteries, packed close. There is a small force-pump which can be worked either by hand or by electricity, and which can be used either for air or water. There is an ordinary electric engine connected direct to the propeller shaft. Near it is a small wheel with simple accelerating gear worked by hand. Still further back are the tillers of the two rudders and the helmsman's seat. Just above the seat is a glass V-tube, one arm of which is attached to the top of the boat. By the aid of clutches, both propellers can be run by the same engine. There is also suspended from the top a water-tight box having a door opening into the interior. The displacement of the boat is such that in its normal position only a small portion of the top appears above the surface. There is on its deck an air and water-tight entrance to the hanging box referred to above. The boat is caused to descend in three ways. The first is by admitting water into compartments provided for the purpose; the second is to connect the electric engine with the propeller beneath the bottom of the boat, which by its revolutions in one direction draws the boat beneath the surface; the third method can be employed only when the boat is moving. When forced ahead by the stern propeller the horizontal rudder is turned downwards, and the boat dives down head first; by reverse processes the boat is caused to rise.

In case of accident to the electric engine, the propeller can be worked efficiently by means of the hand-wheel and accelerating gear. The depth of the boat below the surface is indicated by the V-tube, mentioned above, which is a simple instrument to gauge the pressure of the water.

Compressed air is carried, stored in suitable receptacles, sufficient for the use of the crew for a long while; but that supply is kept in reserve. A supply of fresh air is ordinarily secured while the boat is below the surface by means of the iron pipe which lies on the deck. When the boat is 15 or 18 ft. below the surface, the pipe is raised to a perpendicular position by a simple gearing, and its bottom comes into position over a valved opening leading to the interior of the boat. As the monitor is only 15 to 18 ft. below the surface and the pipe is 20 ft. long, the end of the latter rises above the surface of the water. By opening the valve and attaching the double air-pump, fresh air can be drawn into the interior of the boat, while the vitiated air can be expelled by the same pump through a valved exit provided for that purpose. The interior of the boat is lighted by an incandescent electric light. There are no windows in the boat, and therefore, in order to direct its course, the captain in submarine armour stands in the hanging box, and thus obtains an unobstructed all-round view. He communicates with the helmsman by means of a telephone, which is attached to the helmet.

The crew need not exceed three men, a helmsman and two others, to manage the air and water pumps and keep everything in order.

Description of the "Goubet."—The "Goubet" submarine torpedo boat is of iron, 16 ft. 5 in. long, 3 ft. 3½ in. wide, and 5 ft. 10½ in. deep, including the look-out dome.

The weight of the boat, with its water reservoirs empty and without the crew, is 3196 lbs., and its displacement when submerged is 4050 lbs. in sea-water. Its buoyancy is therefore 860 lbs., and the boat is submerged by the weight of the crew and the water admitted to the reservoirs.

Each man requires about 14 cubic ft. of air per hour. To provide for this a reservoir contains air at a pressure of 50 atmospheres, in sufficient quantity to last the crew of two men for 10 hours. The carbonic acid and the other acids are absorbed by chemicals, and an air-pump expels the foul air.

To drive the boat at its maximum speed of 5 knots, a power of 0·553 H.P. is required, and may be furnished by a Siemens motor, working from accumulators. (This would necessitate a considerable weight for motive power.)

There is no rudder, but a universal joint in the screw-shaft permits the screw to move through an arc of 90° on each side.

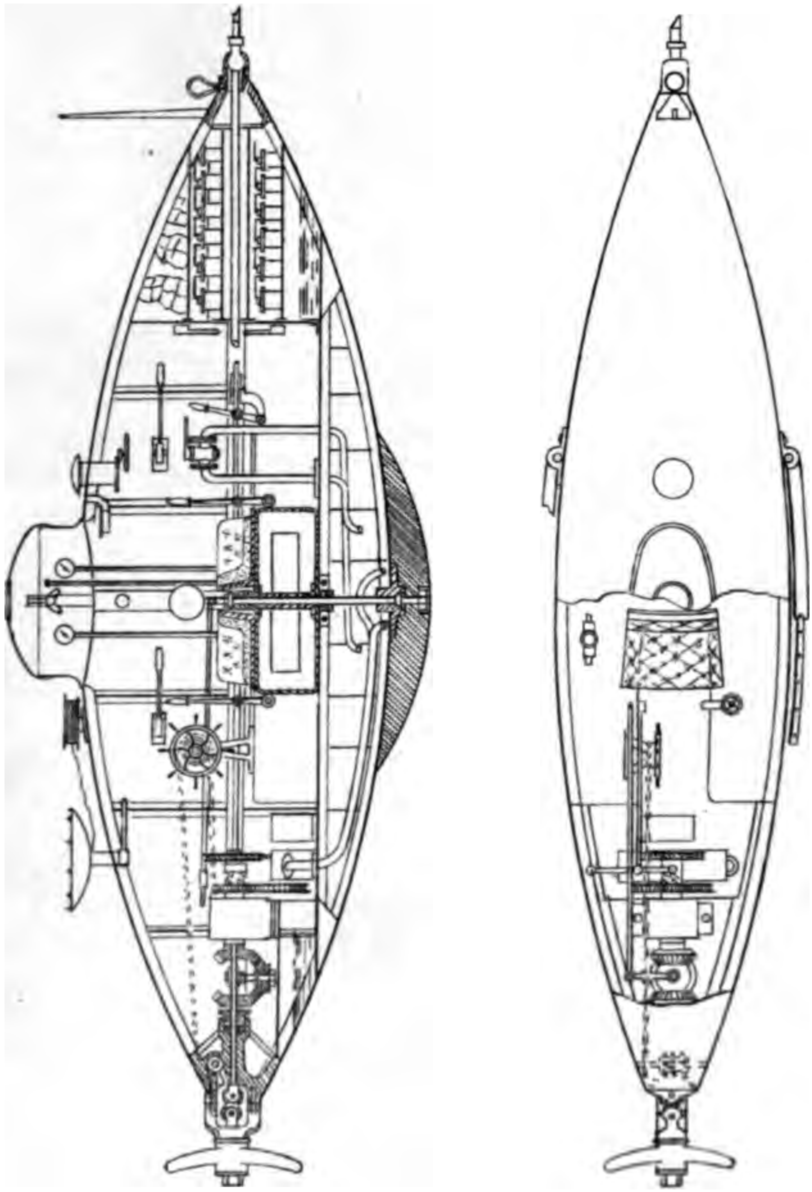
In submarine boats it is essential that the trim should be very exact, as otherwise the motive power might cause the boat to jump out of water or dive to unsafe depths. To maintain the trim in the "Goubet" boat there is a water tank at each end of the boat connected with a double-acting pump, which draws and delivers in opposite directions, according to the direction of motion of its operating shaft. This shaft ends in a crown wheel, which may gear with either of two wheels on a shaft at right angles to the first, and revolving constantly in the same direction. As long as the boat remains with its axis horizontal the pump is motionless, but on any change of the axis a pendulum throws the pump into gear with one of the two wheels on the second shaft, and water is pumped from the lower to the higher tank, bringing the boat to a level axis.

The torpedo is carried outside the boat and is secured by a bayonet-catch controlled from the inside. On arriving under the enemy, the torpedo is released and rises by its reserve of buoyancy until it catches on the vessel's bottom by spikes, with which its upper surface is provided. The torpedo boat then withdraws, maintaining its connection with the torpedo, by unreeling a wire. When the boat is at a safe distance the torpedo is exploded.

The boat is also provided with a small torpedo which, when released, rises to the surface and explodes, forming a signal which by

"GOUBET" SUB-MARINE BOAT.

PL. LXXVI



its noise and the colour of its flame calls attention to the boat and indicates the depth at which it is. The torpedo may also carry up a telephone wire.

A large weight is attached to the bottom of the boat by a screw and nut, and may be released at any time, thus permitting the boat to rise.

In case the motor breaks down there is an arrangement for working two oars which habitually trail alongside. These oars fold longitudinally. When in use they open at the stroke and close at the recover.

To attack a vessel the boat proceeds along the surface until it is thought necessary to dive, when the captain directs the boat at the enemy by the sight-vane; the other man maintains the course by compass, and the boat sinks by admitting water to the tanks.

It is stated that three hundred of these boats were ordered for Russia in 1881, and that fifty were delivered in 1883. The early form of the boat was driven by manual power. This submarine boat is shown at Pl. LXXVI.

Description of the "Holland."—This submarine diving boat is the invention of Mr. J. P. Holland, of the United States.

This boat, which is shown at Pl. LXXVII., is 31 ft. long, 6 ft. in diameter, circular in cross section, and some 16½ tons displacement. She is provided with a 25-H.P. petroleum engine, air-compressing machinery, and a 9-in. pneumatic gun. She can carry fuel enough for a two days' continuous run. The speed either on or below the surface is 9 miles per hour, but only 6 miles an hour is permitted below the surface.

A, A are air tanks of 105 feet capacity; *W, W*, water tanks; *P* the pneumatic gun; *a* air compressor, and *G* charge for same.

The diving is effected by means of two horizontal rudders placed one on each side of the stern: in the original boat an attempt was made to submerge it bodily by means of bow and stern horizontal rudders, but this was found impracticable in the absence of great speed, and so the system of diving was resorted to. The Inventor states that he has never succeeded in making this boat stick in the mud at the bottom even when run at full speed at a considerable angle of inclination.

A new "Holland" is now being constructed which will be 50 feet long, and 8 feet in diameter. She will be provided with 60-H.P. engines, and with a 10-inch submarine pneumatic gun 20 feet long, capable of throwing a 200-lb. blasting gelatine shell 1000 yards over, and 200 yards under water.

Description of the "Nautilus."—This submarine boat was designed by Mr. A. Campbell, and differs very materially from other vessels of this class in regard to the manner in which its submersion is effected.

The "Nautilus" is some 60 feet long, with a diameter of 8 feet amidships, and is of circular section. It is pointed at both ends like a cigar, and has on the top a superstructure, on the middle of which is a conning tower with four lenses of glass. The hatch for access to the vessel is placed on the superstructure. It has a displacement of 50 tons when fully immersed.

The submersion is effected by alteration of displacement in the following manner; four cylinders are provided on each side of the vessel opposite to one another, so that they can be worked in pairs; the displacement can thus be varied by one or more of these pairs of cylinders being either pushed out beyond the side to increase, or drawn in flush to decrease the displacement.

At Pl. LXXVIII. longitudinal and cross sections and plan of the "Nautilus" is shown, where *A*, *A*, *A* are the aforementioned cylinders; *E*, *E*, guards; *B* a shaft turning in a fixed bearing *C*, having a right and left handed thread on it; *D* is a spoke wheel; *F*, *F*, propellers; *G*, *G*, a conning tower provided with bull's eyes *H*, *H*.

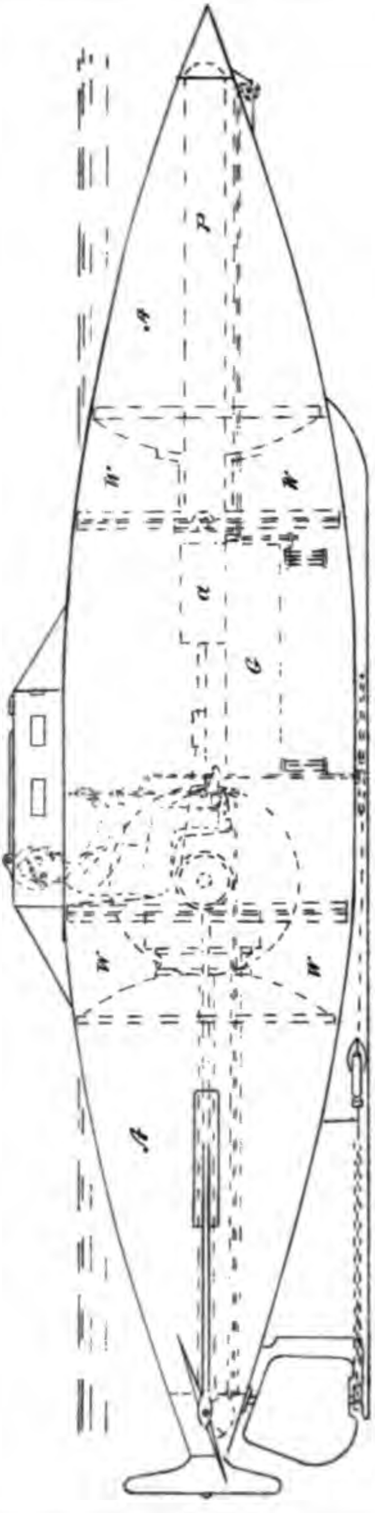
Description of the "Nordenfelt."—The "Nordenfelt" submersible torpedo boats, four of which have been built, have created a considerable amount of interest on account of the novelty of the methods adopted for their propulsion and submersion, and more particularly because these vessels present a very possible solution of the problem of the practicability of this class of torpedo boat for actual service; while another very noticeable feature in relation to these "Nordenfelts" is the vast improvements in the important features of such a vessel that have been effected in each successive boat.

The first of these boats was built in 1883. Her dimensions are 64 feet in length, 9 feet in diameter amidships, with a displacement of 60 tons.

The principal features of this vessel are (1) steam propulsion; (2) submersion by two propellers placed in sponsons *amidships*, one on

“HOLLAND” SUB-MARINE BOAT.

..LXXVII.



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PORTSMOUTH

each side, and arranged to give their effect in a vertical direction; (3) armament of *Whitehead* torpedoes; (4) a speed on the surface of 9 knots; and distance travelled on the surface without recoaling, 150 miles.

This boat was purchased by the Greek Government, after the satisfactory result of experiments carried out at Landskrona, before naval and military representatives of most of the civilised Powers of the world.

The second and third boats were constructed for the Turkish Government.

Their dimensions are 100 feet in length, 12 feet in diameter amidships, with a displacement of 160 tons; speed on the surface 12 knots per hour; distance travelled without recoaling 900 miles, with coal in the water ballast tanks; depth to which they can safely descend, 50 feet.

In these boats the two horizontal submerging screws were placed one at each end in the fore and aft line, on the *top* of the hull instead of on each side *amidships*, as in the first boat; by this arrangement it was found in practice much easier to maintain the boat in a horizontal position, while being drawn below, and while running under the surface. In other particulars these boats were similar to the first one, but with the addition of the improvements which experience with the original boat proved to be necessary.

The fourth boat is a distinct advance on its forerunners, more especially in the matter of surface speed, as well as in size and in the internal arrangements.

This boat is 125 feet long, 12 feet beam, and displaces when entirely submerged 250 tons, and when light (running on the surface) 160 tons.

Her propelling machinery consists of a pair of double-cylinder vertical compound engines, working upon four cranks diametrically set; the high pressure cylinders are 15½ in. diameter, and the low pressure 27½ in., with a stroke of 16 inches. These engines indicate 1000 H.P., and propel her at 15 knots per hour. Her speed under water is only 5 knots, though of course she can be driven as fast, or even faster, when entirely submerged, than on the surface, but prudence dictates the slower speed for submerged runs. The midship section is a circle, while a section at any other point will show two arcs of a circle, the vertical centre line of the section being the chord of the arcs. A deck is placed on a spreader where the arcs become small at each end, to strengthen the hull.

The spaces under these decks are divided by bulkheads into tanks, which being filled with water, or emptied, effect the balancing and displacement of the vessel. The coal bunkers, holding 8 tons, are situated in the centre of the boat. The centre of gravity in the most unstable condition of the boat is 6 inches below the centre line, and the meta-centre 2 inches below the centre of the boat.

The tanks carry 35 tons of cold water, and the boilers 27 tons of hot water.

This amount of hot water, together with the iron, cinders, and lagging of the boilers, holds sufficient heat to drive the boat a distance of 20 knots.

The cold water tanks when empty give sufficient buoyancy to the boat to render her entirely seaworthy for surface runs.

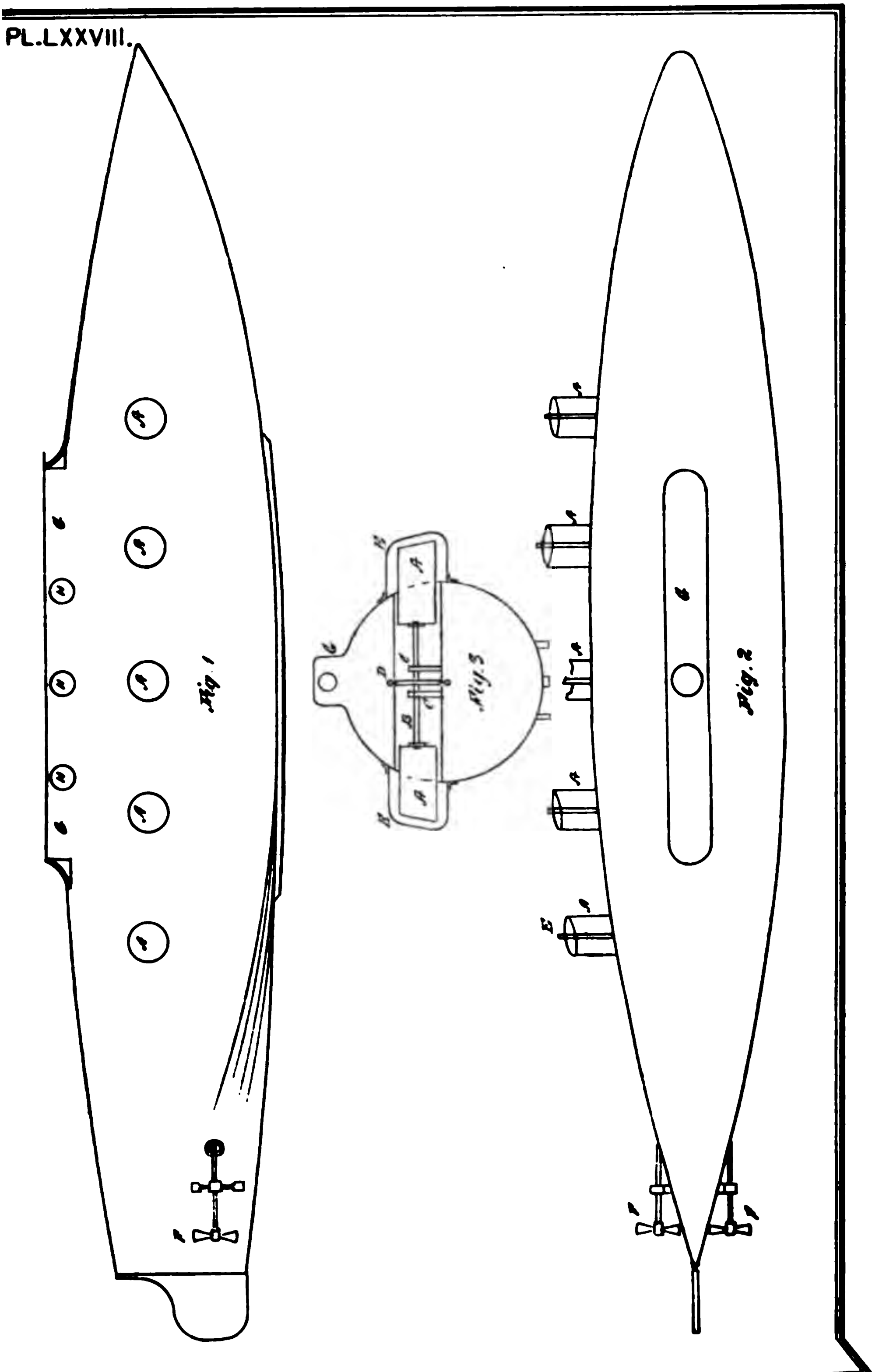
The coal endurance of this boat represents a run of 800 miles at 10 knots, or 1000 miles at 8 to 9 knots; for long voyages 20 tons of coal in addition may be carried in lieu of water in the tanks.

The submersion of this boat is effected by two horizontal propellers working in wells one at each end, and in this case *below* the water line; by this arrangement the advantages of maintenance of horizontality when being, or running submerged, as practically demonstrated in the two Turkish boats, are retained, with the further gain of not creating any disturbance on the surface during the process of immersion, or when running just below the surface.

These horizontal propellers are worked by separate engines entirely under the control of the captain in the conning tower, who can thus regulate the rate and depth of submersion, which depends on the speed of these propellers, and the time they are kept in action, and he can also vary their respective speeds for the purpose of keeping the boat horizontal; if after being submerged it is desired to ascend to the surface, it is only necessary to stop these propellers, when the reserve buoyancy which the power developed in these propellers has overcome, will cause her to rise at once to the surface. An arrangement is provided by which the two submerging propeller engines are automatically stopped when the boat has reached a previously arranged depth.

"CAMPBELL & ASH" SUB-MARINE BOAT.

PL.LXXVIII.



Horizontal bow and stern rudders can also be provided to assist in keeping the boat horizontal, and to bring her to the surface should she be caused to attempt to dive by some unexpected force. These rudders are however not absolutely necessary, and the boat is now being run without them. When used they are set in different directions, and act automatically, though also under the control of the captain.

The boat is provided with two conning towers, 2½ feet diameter, of 1-inch steel, standing about 2 feet above the deck, and are surmounted by glass caps or domes protected by steel bars to supply a means of look out when the boat is sealed up.

In the forward conning tower are located all the necessary connections for giving the captain command of all the machinery for driving and steering (steam) the vessel, for sinking or rising, for controlling the fans, for controlling the horizontal propellers, and for discharging the *Whitehead* torpedoes; in this tower are also placed the instruments for showing the depth, the level, and the course.

The boat is lighted by candles, which show the composition of the air in the interior when sealed up. The crew consists of the captain and eight men.

In addition to the ordinary fittings of a submarine boat, this "Nordenfelt" can carry mast, side lights, compasses, anchor, &c., as in the case of an ordinary surface torpedo boat.

There are two *Whitehead* discharging tubes placed in the bow, and room is provided for two spare torpedoes, or four in all; it is also proposed to arm the boat with two Nordenfelt 2-pr. quick-firing guns. The armament is however a matter to be settled by the Government who purchases the boat.

When the boat is in the awash, or partially submerged position, which is brought about by filling her cold water tanks, she floats with only her two turrets showing above the water; the funnels have previously been unshipped, and the boat completely sealed or closed up; she may then be drawn down by her horizontal propellers until only the two glass domes are in sight, or entirely submerged to any depth up to 50 feet (the boat is actually constructed to withstand the pressure at 100 feet). The reserve buoyancy is never less than half a ton. Pumps are provided capable of emptying the tanks at the rate of a ton and a half a minute.

At Pl. LXXIX., Fig. 1, is an elevation, Fig. 2 a longitudinal section, Fig. 3 a plan, and Figs. 4 to 9 cross sections of the latest type of "Nordenfelt" submarine boat.

A is the propelling engine; *B B'* the boilers; *b b'* the coal bunkers; *a*, *a'* the submerging or descending engines; *C*, *C'* the submerging propellers; *D* the driving propeller; *d* the torpedo launching tubes; *e* the shaft for opening the door of launching tube; *f*, *f'* the conning towers; *g* the tube enclosing steering shaft; *h* air compressing engine; *i*, *i*, *i* bunks; *m* cooking range; *n*, *n*, *n* water ballast tanks; *o*, *o*, and *o'*, *o'* horizontal rudders; *p* vertical rudders.

All the Nordenfelt boats have demonstrated most conclusively in official trials at different times their efficiency and also their safety as submersible boats, and there only remains to be proved their capability and utility for naval warfare. For a satisfactory settlement of this latter point, it will be necessary for this class of torpedo boat to be submitted to a series of exhaustive experiments under the direction of naval officers, such as for instance the attack of a ship under way in the day time and under cover of darkness, similarly of a vessel at anchor, and further the attack of the submersible boat by one or more surface torpedo boats supposed to belong to the defence; in making her attacks, the submersible boat should do so alone, and also supported by surface torpedo boats.

Messrs. Nordenfelt, Goubet, Tuck, Holland, and Campbell, have shown that submarine and submersible boats are feasible, and it now remains for some one or other of the principal Naval Powers to take up the question and prove their fitness or otherwise for actual service.

Some insight into the present condition of submersible boats having been given by the foregoing descriptions of the more prominent ones, the consideration of the various reasons which may be alleged for their hitherto non-adoption will now be proceeded with.

The Property of Submergence too prominently put forward.—The property of being propelled through the water when wholly submerged at considerable depths, though a distinctive and important feature of submersible torpedo boats, has been commonly and erroneously treated as being the sole object of their construction, instead of being looked at as merely a means to an end; in other words, this class of vessel has been usually spoken and thought of as always doing its work in its submarine state, and has thus caused an adverse feeling to be established against their employment, because of the danger heretofore

PL.LXXIX

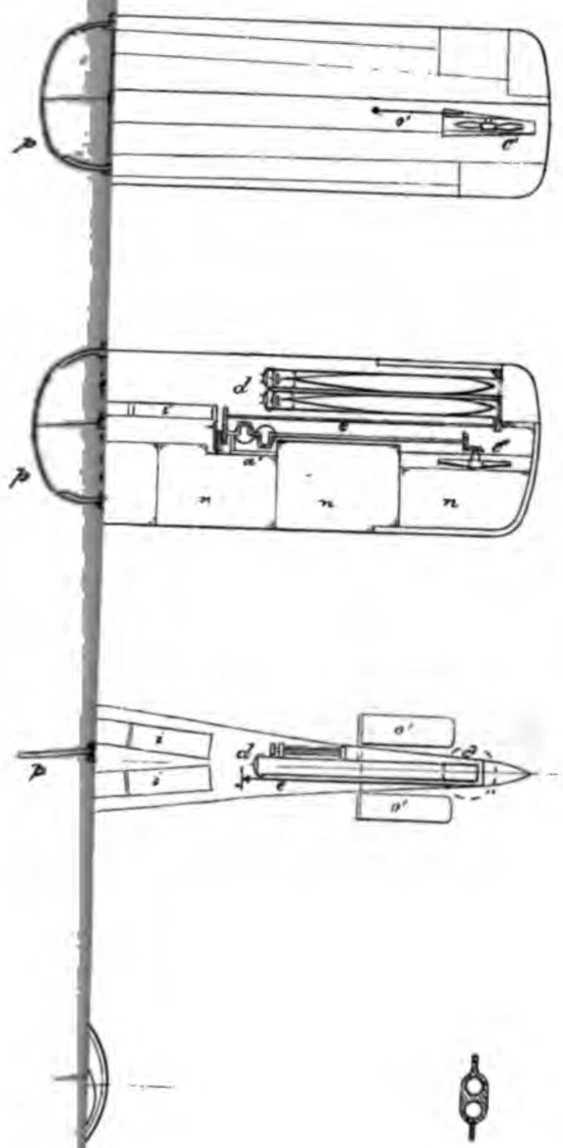


Fig. 10

considered inseparable from this service, and also because of the uncanniness attributed to this mode of attack.

The Question of Danger in a Submerged Run.—The question of danger in running a boat beneath the surface of the water is one of degree, for though doubtless a fair objection in connection with submarine boats of the past, yet, nowadays, with the improved knowledge of such vessels, to judge from the experience gained with those of more recent construction, it would appear a less hazardous undertaking to make a submerged run in one of them, than a full speed run in a surface torpedo boat; as this is, however, a matter intimately connected with the questions of the system of submersion employed, and of speed, its consideration must be reserved until these properties come to be discussed.

The Objection of Uncanniness.—The objection raised on the score of uncanniness in the manner in which a submersible torpedo boat will make its attack cannot be applied solely to this class of vessel, for it is applicable in any equal degree to every branch of torpedo warfare; what can be more uncanny, for instance, than the submarine mine, secreted as it is beneath the surface of the water, ready at any moment to deal its terrible blow? Again, a surface torpedo boat, though in itself an object to be seen, yet, when armed with the "Whitehead," delivers its blow in what might equally be said to be an uncanny fashion; while, what is more uncanny than land mining?

The feeling that an attack made on a ship which is wholly unseen, *i.e.* when executed by a totally submerged boat, is not a fair, and certainly not an above-board mode of warfare, can be well understood; but this question resolves itself into one of *tu quoque;* what one Naval Power does in the way of adopting new engines of destruction must be followed by the other Powers, even against their will, provided of course that it possesses decided advantages.

The term uncanniness in connection with a submarine boat would appear more applicable to the feeling engendered in a crew conducting a wholly submerged run for the first time, but this is of course simply a question of experience, and any feeling of unpleasantness and danger would soon pass off provided that the system of construction of the boat be known to be a proper one, and as soon as the crew gained confidence in its safe working, and in their commander, in whose hands lies the whole responsibility of safely manœuvring his charge.

No difficulty of any sort has been experienced in obtaining officers and men for any kind of submarine boat, and the well-known story of the Confederate boat, in which three crews were lost during practice, and for which a fresh crew volunteered in its fourth and final trip, proves that any how, in a time of war, there will be no lack of volunteers for manning these vessels.

The want of a proper Torpedo Armament.—The torpedo armament of submarine boats has previously consisted either of a spar torpedo, or of a submarine mine intended to be fixed to the ship's bottom by a diver emerging from the attacking boat, or floated up to the ship's bottom on being freed from the boat. Either of these methods unquestionably constitutes an objectionable feature, inasmuch as this mode of delivering its blow obliges the submarine boat to approach into too close a proximity to the hostile ship so as to render this an exceedingly hazardous undertaking, not alone because of the risk that naturally attends a submarine boat which is obliged to pass under the bottom of a ship, or in the case of the spar torpedo to come practically into contact therewith, but also on account of the possibility of the "Engineer being hoist by his own petard."

In the "Tuck" and "Goubet" systems *one* of these dangers is certainly evaded by attaching a long length of electrical wire to the mine and firing it at a distance; in the "Holland" system a pneumatic submarine gun is used, having, it is said, a range of 200 yards; and in the "Nordenfelt" system the *Whitehead* torpedo, having a range of some 300 to 400 yards, is employed, and in both of these latter cases a considerable advance has been made in the mode of attack of the submarine boat. It may be laid down as an axiom of submarine torpedo boat warfare that the greater the effective range of the torpedo armament, the greater is the safety of the attack; for even with a pneumatic gun, or with the *Whitehead*, there is a probability of the submarine boat when wholly submerged, and therefore not so well able to judge distance, overrunning its distance, and coming dangerously close to the area of explosive effect of its own torpedo.

If only a *controllable* torpedo be devised which would be absolutely reliable at a range of say 1000 yards, the power of attack of a submersible torpedo boat would be immensely increased, for then she need rarely resort to complete immersion, as at this distance she would be practically invisible when only *partially* submerged. Another weak point in the armament of the submarine boats of the past, and of even the smaller ones of the present day, is to be noticed in the absence of any gun defence, but this defect has been overcome in the latest types of "Nordenfelt" boats by the provision of one or more machine, or light quick-firing guns.

The want of Adequate Size and Strength.—A conspicuous feature of the submarine boats hitherto and usually constructed for war purposes is their want of size, and this has had a decidedly deterrent influence against their adoption, because inefficient dimensions means incapability of providing a combination of those qualities which are now understood as requisite for the realization of an efficient submersible torpedo boat, such as; (1) High speed; (2) Keeping the sea in all weathers for several days at a time; (3) Sufficient length of submerged run; (4) A coal endurance of several hundred miles; (5) An internal capacity sufficient to enable her crew to remain closed up for several hours without calling in the aid of special apparatus to renew and purify the air; (6) Capability for carrying an efficient torpedo armament, such as the "Whitehead," and also a small gun defence; (7) Structural strength for a maximum submergence of 100 feet, without fear of the hull collapsing, or of being dangerously compressed; (8) The provision of armour on the top sides.

It has been proposed to provide the smaller submarine boats as part of the equipment of men-of-war, but these are practically useless for any purpose other than that for which they are designed, but in a time of peace the larger boats could be utilized in a variety of ways, while in war time, besides their special duties as a torpedo boat, they would prove invaluable as despatch vessels.

If a submarine torpedo boat is ever to become accepted as an useful adjunct of naval warfare, then large size and consequently increased cost must be faced as an absolute necessity.

The Method of Propulsion.—Manual labour, compressed air, electricity, and steam, have each been utilized for submarine boat propulsion, the former being the more prevalent; in fact this was the only method used up to within the last few years, while it is even now resorted to in the case of some of the Russian vessels. Manual labour is, however, altogether out of the question in connection with the type of submarine torpedo boat required in these days, owing to its want of power and cumbersomeness.

Electricity and compressed air have so far failed to afford satisfaction as the propelling agent of this class of vessel, principally because of want of power.

Steam propulsion has, on the other hand, though possessing some disadvantages, in the case of the "Nordenfelt" (No. 4) vessel, demonstrated its suitability in most respects, especially in the matter of high speed and endurance; this propelling agent has one defect in the length of time occupied in closing up the boat, caused mainly by the time (25 minutes) required to house the funnels; but this operation could probably be performed in much less time by a skilled crew, and the present system of housing the funnels is open to improvement, and will doubtless be altered in the next boat.

It has been proposed to combine steam and electrical propulsion for submarine boats, the latter to be utilized in submerged runs only, but it is questionable whether with the present condition of electrical propulsion any practical advantage would thus be obtained.

It might be surmised that a boat entirely sealed up for several hours, when using steam propulsion, would become unpleasantly hot, but this has been proved not to be the case, as in the "Nordenfelt" (No. 1) small boat, after a submerged run of 14 knots for some 3 hours, the thermometer registered only 90° Fahr., which is considerably cooler than most stokeholds and engine rooms of ordinary steamships.

While as to the purity of the air, four men have been closed up in this same boat for six hours, without any appreciable diminution in the length of the flame of a tallow candle placed on the bottom of the boat, where the greatest impurity of the air would be experienced.

Insufficiency of Speed.—This lack of speed possessed by submarine boats up to the advent of the "Nordenfelts" has unquestionably been one of the main reasons of their not being adopted, and more especially is high speed a desideratum in these days, because of the increased speed of all men of war, and the presence of the fast surface torpedo boat.

High speed is necessary to a submarine torpedo vessel to enable it to cope with its rival the surface torpedo boat, to make a rapid passage from port to port, and to overhaul a hostile ship attempting to escape; and this factor of high speed is required not only when the vessel is running on the surface, but also when partially or even when wholly submerged. For the greatest danger the submarine boat will be exposed to is when attacked by two or more steam boats armed with the spar torpedo, and these need not necessarily be special torpedo boats, provided only that they have a higher rate of speed than the submarine boat when *wholly submerged.*

For though, so far as the engine power of a submarine vessel is concerned, she should be able to steam for a short time at a higher rate of speed when wholly submerged, than on the surface, as has been proved in the *Whitehead* experiments, yet in this condition there is the very great risk of the submarine vessel, if driven beyond a speed of some 5 knots, being caused to dive; and in deep water, owing to the comparatively small amount of the reserve buoyancy, of reaching to a depth beyond the structural strength of the hull, before the corrective forces against a dive have had time to force her to assume an upward direction; there is not only the fear under these circumstances of the boat collapsing, but also of its being compressed sufficiently to seriously reduce its displacement; while in shallow water there is the risk of the boat being driven on to the bottom, and if it be mud or clay, of her being held there.

The greater the length, weight, and speed of the boat, the greater the likelihood of its making a dangerous dive. There is, besides, a further danger to be apprehended in running at full, or even at slow speed, when wholly submerged, from the fact of its being impossible to discern objects right ahead.

As to this interesting and important question of visibility from a submarine boat running beneath the surface, Mr. Nordenfelt states as follows:—

"As to the light, we have never been down more than 16 feet, but at that depth there is plenty of light from the surface of the water. The mirror of the surface throws a very strong light inside the boat. You cannot see fore and aft except at the angle at which the water above you, acting as a lens, reflects objects on the surface. What that angle is I have not ascertained absolutely, but it is a tolerably large angle. You cannot see far forward at all, and you cannot see far astern, it is as black as ink, you can only see a sort of segment. You cannot see forwards, that means that you cannot safely advance at great speed under water, that holds at least until it has been proved to the contrary. It is impossible to think of a submarine boat as a boat that actually manœuvres and does its work under water; I gave that up from the very commencement. I do not believe for a moment that a man can go down and steer about for great distances, and attack right and left; the risk is too great. He should run awash, and then he would see where he was." *

Thus it is clearly evident that, if alone for the inability to see any distance ahead, a submarine boat wholly immersed ought not to exceed the limit of speed which practical experience has fixed at 5 knots; of course when only partially submerged the question of diving alone limits the speed, because in this state a clear all-round view can be obtained from the conning towers.

As it must be admitted that a submarine boat would be very considerably enhanced as a torpedo boat by possessing the power of running at full speed while *partially* submerged, and as it is now an accepted fact that the condition of *total* submersion should only be resorted to under certain special circumstances, such as in defending itself against the attack of surface torpedo boats, it would seem worth the attention of naval architects to devise a torpedo boat capable of running at its highest speed, whether on the surface or *partially* submerged, and give up the idea of total submersion.

The comparative merits of two torpedo boats, one capable of running at the rate of 17 knots, either on the surface or when partially submerged, but without the power of total immersion, and the other able to run at the same rate on the surface, but only at some 5 knots, when partially or wholly submerged, admits of much argument; the question turns on the power of high speed, and therefore great handiness comparatively in partial submergence (only the conning towers in sight), versus absolute invisibility and slow speed.

It must be remembered, in considering this point, that under-water navigation is most uncertain, and that in attacking under the cover of darkness the state of partial submersion is a state of practical invisibility, while even in daylight at slow speed it is sufficiently so for all practical purposes.

The Methods of Submersion.—The dangerous character of the earlier systems of effecting the submersion of submarine boats was another strong reason for causing them to be looked upon with disfavour, due to the fact that in these methods the necessary element of safety, a

* Lecture on Submarine Boats, by Mr. Th. Nordenfelt, published in the R. U. S. Journal, 1886 (No. cxxxiii.).

certain amount of reserve buoyancy, which, under no circumstances, should be reduced or destroyed, was ignored.

Thus any accident happening to the apparatus for discharging the water, or lead (ballast), usually worked by manual labour, was bound to result in the loss of the boat. This imperfect system of submersion is even now adopted in some of the latest submarine boats.

The experience gained from the manipulation of submarine boats of various systems during the last two hundred years teaches the following lessons as to the necessary properties of an effective and safe method of submersion:—

1. The maintenance at all times, and under all circumstances, of a reserve buoyancy, the minimum amount of which should depend on the size of the boat, and which should be as large as it is feasible to make it.

2. The overcoming, not destroying, of this reserve buoyancy for the purposes of submersion by *mechanical* means only, in such a manner that only while it is in operation can the boat be kept immersed, so that any accident happening to the latter must cause the former (reserve buoyancy) to come into operation to cause the boat at once to rise to the surface.

3. The provision of powerful pumps to eject any leakage of water, which might otherwise in time destroy or reduce to dangerous limits this important factor of safety (the reserve buoyancy), and apparatus for enabling the instant detection of any leakage.

4. The capability for immersing the boat when in a state of rest.

5. The maintenance of horizontality during the process of submergence, and also while running beneath the surface.

6. The provision of automatic means for keeping the boat at any specified depth.

7. The whole of the apparatus for effecting the submergence, and maintaining the boat horizontal, to be under the immediate control of the captain, who should also be provided with instruments for registering the degree of inclination (if any), and state of air in the boat.

The important factor of safety, the retention of a reserve buoyancy, is a feature common to the "Tuck," "Holland," and "Nordenfelt" systems, but all the other properties consistent with securing absolute safety in submerging a boat, and running it when submerged, as before enumerated, are only to be found in the latest type of "Nordenfelt," the No. 4 boat.

The "Tuck" system provides for immersion when the boat is at rest, by the admittance of water, and also by a single horizontal propeller beneath the bottom of the boat, and it can also be caused to dive when moving through the water by horizontal stern-rudders, but it lacks the most important property of any satisfactory means for maintaining horizontality during the process of immersion, or during a submerged run.

The feature of the "Holland" system is that immersion is effected by causing the boat to *dive* by the aid of horizontal stern rudders, and therefore it lacks the essential property of horizontality, as well as of immersion, when in a state of rest.

It may be noted here that Mr. Holland originally tried the plan of horizontal submersion by means of bow and stern rudders, but found that this was necessarily a very slow process with the boat moving at the slow speed which safety considerations demand for a condition of submergence, and therefore he had, perforce, to give this method up, and now believes that *diving* is an essential feature of a submarine boat.

In the case of a very small submarine boat, immersion by diving may not be so dangerous a process, but for vessels of suitable dimensions for properly fulfilling the duties of a submarine torpedo boat this method is inadmissible, owing to its dangerous character.

The "Nordenfelt" system of submersion, as exemplified in his more recent boat, No. 4, satisfies in every particular the requirements of a safe and efficient means of submergence before stated; this system includes an ample reserve buoyancy of at least *half a ton*, which, except by unforeseen circumstances, as, for instance, a leak, is always retained, whether the boat be wholly or only partially submerged; two horizontal propellers, one at each extremity of the boat, working vertically by separate engines, so that they may each be run at different speeds, or one altogether stopped, or one reversed, for the purpose of maintaining the horizontality of the boat at all times. With a careful captain who closely watches the instrument which registers any inclination of the boat upwards or downwards, there should be no danger of the boat ever getting more than a degree or two out of the horizontal, and no possibility of diving.

These two horizontal propellers are the mechanical means by which the boat is drawn *bodily* under the water, *i.e.* the reserve buoyancy acting upwards is *overcome*, not destroyed, and therefore is always tending to bring the boat to the surface; the time of immersing the boat to any desired depth depends upon the rate these propellers are run at, and, by reversing them, an additional power of ascension is obtained.

Automatic apparatus is also provided, by which these propellers are stopped automatically at any set depth, and similarly set going again when the boat has ascended above this depth; the captain has at the same time control of the submerging engines, independent of the automatic arrangement.

The amount of reserve buoyancy may, of course, be increased, necessitating additional power in the submerging engines, either by decreasing the amount of hot water carried, or by enlarging the dimensions of the boat.

Besides the reserve buoyancy and the reverse action of the horizontal propellers, the upward force may be increased very rapidly by blowing out the hot water (27 tons), and still further by discharging the 35 tons of cold water, for which latter purpose, and also for the overcoming of any leak, powerful pumps are provided; so that the normal factor of safety can be greatly added to in case of an untoward accident.

It must not be supposed that this strong commendation of the "Nordenfelt" method of submersion applies to the "Nordenfelt" submarine boat as a whole, for it has yet to be demonstrated that steam is the best form of propulsion for such vessels, and that the Nordenfelt or any other submarine boat can be made effective for torpedo operations; but the principle of submersion therein adopted is most assuredly the right one.

APPENDIX.

APPENDIX.

EXPLOSIVES FOR SUBMARINE WARFARE.

THE following summaries and data are taken from General Henry L. Abbot's U.S.A. report (1881) on Sub-Aqueous Explosions.

I.—*Summary of Results with Explosive Mixtures.*

I.—The nitrate mixtures would be far inferior to the chlorates for use in torpedoes were it not for the dangers attending the handling of the latter. How much this should weigh in deciding between them will depend upon local circumstances.

II.—If gunpowder be chosen as the explosive, the finest and the quickest grades are the most economical—indeed, none other should be employed.

III.—Numerous well-distributed points of ignition are very desirable; and if large detonating primers are available, they should be used.

IV.—Strength of case is of the highest importance. A small charge in a strong iron torpedo, when fired in the close vicinity of the enemy, is as effective as three or four times the amount in a wooden torpedo. Also, the nearer the form of case approaches a sphere the better.

V.—An air chamber in the torpedo, equal to the charge in dimensions and cubic capacity, is decidedly advantageous, because it serves to direct the blast. This advantage is greater with stationary than with movable torpedoes, the increased bulk being an objection in the latter case.

VI.—The relative strength of the different explosive mixtures for use under water appears from these experiments to be the following, mortar powder being adopted as the standard :—

Mammoth powder	0·08
Cannon "	0·18
Mortar "	1·0
Sporting "	2·61
Safety compound (chlorate)	30·62

An instantaneous photograph of the explosion of an iron torpedo, containing 276 lbs. of mortar powder, resting on the bottom in water 10 feet deep, is represented in the frontispiece.

Distance from camera, 300 feet; height of jet on plate, 157 feet; probable total height, 280 feet.

II.—*Summary of Results with Explosive Compounds.*

I.—Dynamite No. 1, compressed gun-cotton, and probably explosive gelatine, are all suitable explosives for the submarine mining service.

II.—No advantage is derived from multiplying the points of ignition with either of them. One heavy detonation within the charge will develop its full power.

III.—A priming charge of dynamite must be kept dry and in the state of loose powder to ensure the detonation of the main charge under all conditions of moisture and temperature. Hence, it should be inclosed in a separate case provided with mechanical devices for preventing packing.

IV.—No advantage is secured by confining the charge in a strong case. Hence, the latter may be made to conform to the mechanical requirements of the problem; provided, however, that its material shall be hard and thin, so as not to absorb an unnecessary part of the energy of the charge.

V.—The moderate air chamber within a buoyant torpedo, indispensable to the requisite flotation, is not objectionable; but it should not be larger than is necessary.

VI.—No fear need be entertained of the sympathetic explosion of one charge from the explosion of its neighbour, or of a countermine, provided the case be of iron strong enough to resist rupture from the shock.

VII.—No danger of deterioration after planting exists either with dynamite or compressed gun-cotton, when proper care has been observed in the manufacture and testing of the explosive.

VIII.—Neither great depth of water nor great submergence is needful to develop the full force of explosive compounds. From 3 to 5 feet is sufficient for 100-pound charges.

IX.—The following figures represent the relative intensity of action of the several explosives when fired under water:—

Explosive gelatine	117
Dualin	111
Hercules powder No. 1	106
Dynamite No. 1 (Giant Powder)	100
Rendrock	94
Gun-cotton	87
Nitro-glycerine	81

III.—*Best Explosive for Submarine Mines.*

The merits to be sought in an explosive for this service are:

I.—The greatest possible intensity of action when fired under water, in such envelopes as are suitable for submarine mines. This condition excludes all of the explosive *mixtures*; and, among the explosive *compounds*, limits the choice to explosive gelatine, dualin, hercules powder No. 1, dynamite No. 1, rendrock, and gun-cotton.

II.—Retention of normal strength under the conditions incident to the service, viz., the lapse of time, alternate freezing and thawing, occasional wetting, and even saturation with water. By this standard, dualin is far inferior to dynamite and gun-cotton, since it is dangerous when frozen, and when saturated loses half of its normal strength; while neither gun-cotton nor dynamite in loose powder are materially affected by water. Hercules powder and rendrock are quite excluded from the list by this condition, since their absorbents are soluble.

III.—Convenience in loading—involving safety in transportation and in handling with ordinary roughness; a form which admits of ready insertion through a hole small enough to be easily rendered water-tight; and, lastly, a high density giving a small bulk. Gun-cotton when wet is quite safe; but its disc or slab form is inconvenient, and when granulated it is bulky. Dynamite with reasonable care is quite safe, but when handled by men not accustomed to its use it often causes headache. In respect to density, even in the shape of loose powder, it has the advantage over either of the others, and it can be readily inserted through a hole 3 inches in diameter. Dualin is unsafe when frozen; is as objectionable as dynamite in respect to headaches; and is also quite bulky. By this standard, therefore, it again appears that dualin is decidedly inferior to the other two.

IV.—Market facilities. It is undesirable that a large supply of any of these high explosives should be kept in store in our forts during peace. Hence, to be readily obtainable in the market in large quantities, is no small merit. Gun-cotton is not manufactured in this country. Dualin is to be had from only one party; and its manufacture is shrouded with so much mystery, and is so often varied, that the product fails to command the confidence of experts. Dynamite is manufactured largely and at reasonable cost by two responsible companies, one near San Francisco, and the other near New York City; and a good article could be supplied as fast as the Government would require it, even in an emergency.

IV.—*Abbot's Formula for Mean Pressure.*

$$P = \sqrt[3]{\left(\frac{6636\,(A + E)\,C}{(D + 0{\cdot}01)^{2.1}}\right)^2};$$

where

P = The pressure in pounds per square inch of surface exposed to the shock.

C = The weight of the charge in pounds.

D = The distance in feet from the centre of the explosion to the surface exposed to the shock.

A = The angle with the vertical passing through the centre of the charge, made by a line drawn from that point to the surface exposed to the shock, reckoned from the nadir and expressed in degrees.

E = Constant =

For Explosive Gelatine	259.
,, Dynamite No. 1	186.
,, Gun-cotton	135.

V.—*Abbot's Formula for Destructive Radius.*

The general formula for the extreme destructive range (R) of a submarine mine charged with an explosive compound and acting upon a first-class ship-of-war, which has resulted from this investigation and from which the foregoing table has been computed, may be placed under the following form for convenience of application. In any particular case, substitute the numerical values of A, E and C, and find R. If the vessel lies at this or at a less distance, she will be destroyed; if at a greater distance, she will escape rupture of the hull. A submergence of the charge properly suited to its size is supposed—say not less than three or four feet for one hundred pounds, and proportionally greater for larger amounts.

$$R = \frac{\sqrt[2\cdot1]{(A + E)\,C}}{8}.$$

By this mode of treatment the results are made general. Suppose, for example, that the strength of the hulls of ships-of-war should be increased. A corresponding change in the constant 8, would indicate the new requirements. Suppose that some new explosive compound should prove to be better suited to the work than dynamite. A new value for the constant E in the general formula just given is all the change that would be required. It will, therefore, be comparatively easy hereafter to keep pace with modern progress; but it must not be forgotten that there will be need of constant vigilance and systematic research.

TABLE XXIII.—EXTREME DESTRUCTIVE RANGES (ABBOT).

Nature of Explosive.	Charge.	Horizontal range.	Vertical range.
	Pounds.	Feet.	Feet.
Dynamite No. 1	100	16·3	18·6
Gun-cotton	100	14·7	17·3
Explosive gelatine	100	18·2	20·3
Sporting powder, 1 fuze per cubic foot	100	3·3	3·3
Sporting powder, 1 central fuze	100	3·1	3·1
Dynamite No. 1	200	22·6	25·9
Gun-cotton	200	20·5	24·1
Explosive gelatine	200	25·3	28·2
Sporting powder, 1 fuze per cubic foot	200	7·4	7·4
Sporting powder, 1 central fuze	200	6·6	6·6
Dynamite No. 1	500	35·0	40·0
Gun-cotton	500	31·7	37·3
Explosive gelatine	500	39·1	43·7
Sporting powder, 1 fuze per cubic foot	500	19·5	19·5
Sporting powder, 1 central fuze	500	16·2	16·2

The following formulæ, and the Tables XXIV. to XXVII. inclusive, are taken from Colonel Bucknill's (late R.E.) series of articles on "Submarine Mining," published in the *Engineering* in 1887:—

VI.—*Bucknill's Formulæ for Mean Pressure.*

$$P = \frac{9\,C\,I}{D}\left(1 + \frac{25}{D^2}\right) \dots\dots\dots\dots (a)$$

$$P = \frac{9\,C\,I}{D}\left(1 + \frac{25}{D^2}\right)\left(1 \pm \frac{A}{90} \times \frac{e}{100}\right) \dots (b)$$

(a) If target and charge be in the same horizontal plane.
(b) If target be out of the horizontal plane.
P = pressure in pounds per square inch of surface exposed to the shock.
C = weight of charge in pounds.
I = relative intensity of action of the explosive, dynamite No. 1 being the unit.
D = being the distance in feet from the centre of the charge to the target.
A = angle between the line joining the centre of the charge and target and the horizontal plane.
e = percentage for particular explosive used, plus if target be above horizontal plane through charge, minus if below.

TABLE XXIV.—VALUES FOR I AND e (BUCKNILL).

Description of Explosive.	I.	e.
Blasting gelatine	142	12
Forcite	133	14
Gelatine dynamite No. 1	123	16
Dynamite No. 1	100	20
Gun-cotton	100	20
Gunpowder	25	35

TABLE XXV.—RELATIVE VALUES OF EXPLOSIVES FOR SUBMARINE MINING (BUCKNILL).

Order of Merit.	Description of Explosive.	Specific Gravity.	Weight of cubic foot in pounds.	Cost per lb. in pence.	Efficiency under Water. Per lb.	Per cubic foot.	Per £.	REMARKS.
1	Blasting gelatine	1·54	96·3	24	142	138	101	
2	Forcite	1·51	95·4	?	133	127	?	The manufacturing cost probably less than of blasting gelatine.
3	Gelatine dynamite	1·55	96·9	21	123	119	99	
4	Dynamite No. 1	1·6	100·0	17	100	100	100	
5	Gun-cotton, dry	1·06	66·0	27	100	66	63	
	„ wet	1·32	82·5	..	80	66	63	25 per cent. of water added.
6	Tonite	1·28	80·0	..	85	68	..	
7	Gunpowder	0·9	56·0	5	25	14	85	

Table XXVI.—Abbot's Analysis of the "Oberon" Experiments, 1874–76.

Number of Experiment.	Explosive. Description.	Explosive. Weight. (C)	Distance. Actual. (D)	Distance. Horizontal.	Angle from Nadir. (α)	Submersion of Charge.	Depth of Water in Feet. At Charge.	Depth of Water in Feet. At Oberon.	Pressure (P) in Pounds per Square Inch on Nearest Point of Hull. Abbot's Formula.	Ditto (P1). Buckwill's Formula.	Remarks. The last Column has been added to General Abbot's Table.
		lb.	ft.	ft.	deg.	ft.					
1	Wet G. C. (disc) .	500	109	100	113	48	48	60	1,235	4,348	Hull shaken. Condenser pipe split. No serious damage.
2	"	500	91	80	118	48	48	60	1,609	5,269	Hull shaken. No rupture.
3	"	500	74	60	125	48	48	60	2,196	6,581	Seriously shaken. No rupture of bottom. Sea connections damaged.
4	"	500	66	50	131	48	48	60	2,612	7,467	Outer plating buckled. Rivets started. No leak. Condenser, &c., seriously damaged.
5	"	500	52	30	137	48	66	70	3,697	9,644	Outer plating much buckled. No leak.
6	"	500	52	30	137	48	48	48	3,697	9,644	Small leaks started. No fatal rupture. Outer skin seriously damaged.
7	" .	500	38½	0	164	48	48	48	5,996	15,918	Fatal shock. Ship sank. Much damage of various kinds.
8	Wet G. C. (slab) .	60	15	15	100	10	30	30	4,927	4,085 (5,106)	Outer skin indented 1½ in. (This experiment is erroneously recorded. C = 75, and P is therefore too small.)
9	Gunpowder . . .	66	3	3	100	9	30	30	4,155	19,541	Fatal local shock. Large hole opened through both skins.
10	Wet G. C. (slab) .	33	4	4	100	9	30	30	19,800	19,480	Ditto. Ditto.
11	Do. granulated	33	4	4	100	9	30	30	19,800	19,480	Ditto. Ditto.

TABLE XXVII.—ABBOT'S ANALYSIS OF THE "CARLSCRONA" EXPERIMENTS, 1868, 1874–76.

Number of Experiment.		Explosive. Description.	Submergence. (S)	Charge. (C)	Distance. (D) ft.	in.	Angle from Nadir. (a)	Pressure (P) in Pounds per Square Inch on Nearest Point of Hull. Abbot's Formula.	Ditto (P1). Bucknill's Formula.	REMARKS.
			ft.	lbs.	ft.	in.	deg.	lbs.		
First series.	1	Dynamite .	7·0	13·0	2	2	90	27,865	32,856	Wooden side. Hole 15 ft. × 8 ft. through timbers.
	2	„	7·7	16·0	3	0	90	20,300	18,240	„ „ „ 8 „ × 8 „ „ „
	3	„	5·7	16·0	2	0	90	35,765	52,200	„ „ „ 10½ „ × 9 „ „ „
	4	„	6·5	10·0	2	2	90	23,395	24,920	„ „ „ 4 „ × 16 „ „ „
	5	„	7·3	13·0	2	2	90	27,865	32,400	Iron „ „ 4 „ × 3 „ „ plates.
Second series.	1	„	9·2	33·0	25	6	90	1,652	1,210	No serious damage.
	2	„	9·2	47·2	25	6	90	2,114	1,731	Leak from loosened rivets.
	3	Rifle powder	9·2	112·0	12	0	90	1,610	2,463	Ship shaken severely. Many rivets started.
	4	Dynamite .	9·2	33·0	15	0	90	3,478	2,205	No serious damage.
	5	„	9·2	66·0	21	0	90	3,442	4,526	Ditto.
	6	„	9·2	33·0	12	9	90	4,358	6,678	Severe shock to vessel. No serious injury.
	7	„	9·2	33·0	4	6	90	22,040	14,718	Hole 14 × 12. Both bottoms ruptured.
	8	Gunpowder .	29·2	660·0	32	3	130	3,813	5,245	No injury to vessel.
	9	Dynamite .	9·2	19·0	10	6	90	3,958	2,003	Ship shaken severely. Plates indented.
	10	„	9·2	19·0	3	3	90	19,950	17,887	Hole 6½ × 2 to 5. Inner skin bulged and crushed.
	11	Gunpowder .	9·2	112·0	5	9	90	3,857	7,669	„ through both bottoms.
	12	„	29·0	660·0	23	9	160	6,114	8,274	„ 100 square feet in outer and 75 square feet in inner skin of bottom. Ship destroyed.

VII.—*Abbot's Iron Target Experiments.*

Description of iron target:—This target was designed to represent a corresponding area of the bottom of H.M.S. *Monarch*, then (1873) one of the most powerful ironclads afloat.

The target, in general shape a quadrangal box, 20 feet square by 3 feet in depth (internal dimensions), was formed of plate-iron, closed on all sides, and supported by fore and aft and athwartship framing, dividing the internal space into 25 partial cells, 4 feet long, 4 feet wide, and 3 feet deep. The bottom and sides were formed of plates $\frac{3}{4}$ inch in thickness, and the top or deck of plates $\frac{1}{2}$ inch in thickness. Great additional strength was given to the structure, as a whole, by the introduction of 17 wrought-iron pipes (4 inches' internal diameter, and $\frac{1}{2}$ inch thick) between the deck and bottom, to facilitate the attachment of the dynamometers and the torpedoes. The external surface was caulked and made completely watertight, no pains being spared to make the target fully equal in workmanship to an equivalent section of the best type of double cellular bottom.

The total weight of the target when ready for an explosion was about 26 tons—placing the deck about 9 inches above the water surface.

To prevent as far as possible any general yielding to the shock, four 1000-lb. mushroom mooring anchors were placed opposite each side of the target, and connected together by twos over the deck with $\frac{7}{8}$-inch chain cables.

A spot having a tenacious clay bottom was selected, and the anchors were placed on the circumference of a circle of which the centre was under the middle of the target. The chains, making an angle of 45° with the bottom, were hauled taut with blocks and falls; knotted together over the target at low water; and strained by a tidal rise of about 8 feet. This reduced the deck height to about 3 inches, and enormously increased the resistance to any upward motion.

VIII.—*Remarks on Iron Target Experiments (Abbot).*

Shot No. 388 (10th June, 1875).—Charge slung from a boom guyed from a small jury mast 24 feet high. The explosion was sharp and ringing, raising a jet of water 25 feet high, which lifted but did not break the boom. The target rolled considerably in the waves, but was not injured.

Shot No. 389 (10th June, 1875).—Charge slung as before, and boom not broken, although thrown violently around. The target was buried in spray, the jet rising higher than the mast. The chain cables rattled, and a large stone was thrown upon the deck.

Shot No. 390 (11th June, 1875).—Loud ring from the target, which rose squarely about a foot in a fine mist, settled back say 9 inches, and then rose again say 6 inches, when a jet burst upward through the central hole

TABLE XXVIII.—SUMMARY OF IRON TARGET EXPERIMENTS. (ABBOT.)

No. of shot.	Charge, dynamite No. 1.				Depth of Water.	Mean Distance. (D)	Pressure per square inch. (Average, 16 gauges.)		
	Point of Suspension.	Sub. (S)	Weight. (C)	Effective Weight.			Observed.	Computed.	Difference.
		ft.	lbs.	lbs.	ft.	ft.	lbs.	lbs.	lbs.
388	13 feet outside No. 15 angle . .	30·0	20	22·4 ± 2·03	42	38·3	773	739	+ 34
389	Ditto. . .	30·0	40	33·8 ± 2·77	42	38·3	1,044	1,184	− 140
390	Central	32·5	30	35·3 ± 2·34	39	30·8	1,522	1,403	+ 119
391	5 feet outside No. 15 angle . .	32·8	50	58·0 ± 4·46	40	35·6	1,674	1,565	+ 109
392	8 feet outside No. 15 angle . .	32·8	75	72·6 ± 4·61	40	37·0	1,851	1,923	− 72
393	8 feet outside No. 14 angle . .	31·8	100	110·3 ± 5·82	40	36·9	2,461	2,337	+ 124
394	Edge between Nos. 10 and 11 . .	30·0	100	87·5 ± 8·96	40	29·8	2,876	3,242	− 366
395	Edge between Nos. 6 and 7 . .	20·0	100	58·9 ± 6·41	40	20·9	3,540	5,305	− 1,765
428	Central	32·8	200	178·5 ± 5·58	42	30·8	4,596	4,956	− 360
478	Central	13·0	200	45·8 ± 2·08	30	12·1	6,523	17,836	− 11,313

to a height of about 15 feet. The deck showed a slight upward bulging, with three small cracks, and a leak was opened in the bottom which caused the target to sink in about two hours. It settled down gently, turning over upon one side, and rested vertically on the mud.

Shot No. 391 (17th August, 1875).—A clear white jet, say 25 feet high, rose close alongside of the target, which rolled gently in the waves caused by the explosion. No damage. A fish was thrown on deck.

Shot No. 392 (17th August, 1875).—A jet discoloured by mud rose very close to the target, throwing mud and stones on deck. No injury could be detected by a careful inside inspection. The rolling, as before, was gentle.

Shot No. 393 (17th August, 1875).—This shot was more serious than any of the preceding. The jet rose under the corner, bulging in that compartment about half an inch, and caused a very slight leak. Much mud fell on deck. A $\frac{7}{8}$-inch bolt head was forced off from a deck plate near the manhole. The jet was high and a little deflected by the target, which plunged in the subsequent waves, but met the blow fairly.

Shot No. 394 (19th August, 1875).—The jet (photographed) was 140 feet high and tinged with mud. The shock bulged the side plates from $\frac{1}{4}$ to $\frac{3}{4}$ inches on the side attacked, and opened some small leaks next bottom plate. The deck indicated a slight bulging upward, near the middle of the target. The rocking in the waves was violent.

Shot No. 395 (19th August, 1875).—The jet (photographed) was 200 feet high. The chains, notwithstanding the heavy strain on them, were thrown about on deck, and the wedges holding down the gauge rods were loosened. Several small leaks were opened, which sunk the target in an hour and three-quarters in spite of the pumps. The chains scored the edges of the deck under the violent plunging of the target.

A survey of the bottom showed every compartment to be so bulged in as to distinctly reveal the fore and aft and athwartship framing; the average maximum depression for the twenty-five compartments was 1·5 inch, ranging from 0·8 inch to 2·2 inches. A long crack extended along the edge of the internal angle iron from No. 14 corner to within 5 feet of No. 13 corner.

Shot No. 428 (18th August, 1876).—The jet rose to a height of 110 feet, and showed by a forked depression in the centre that its form was modified by striking the target. Of the sixteen $\frac{7}{8}$-inch chain cables, seven were snapped and two others were let go, one by the breaking of a shackle and the other by the yielding of the anchor ring. Corner 16, with both its adjacent sides, was thus left free; indeed, only one complete connection from anchor to anchor remained over the target, and this was parallel to and next the side 14–13. With a telescope on shore the target was distinctly seen to rise, say 2 or 3 feet, before being enveloped by the jet. The vibration of the earth was noticed at a distance of 5 miles with a mercury seismometer, the shock arriving in about 5 seconds, while the jet was still high in the air. The target sunk in thirty minutes from injuries received.

The survey, after raising, showed so much general disorganization that, although there was no open rent, the question of repairs was a doubtful one. The bottom angle irons were broken and rivets sheared along all the four sides, and along about half of the bulkhead frames. Every bottom strake of plating showed cracks, some longitudinal and some transverse, the length ranging from a few inches to 4 feet; the inward bulging of more than half of the compartments exceeded 2 inches; the corner straps were all loosened; many bolt heads were gone; and, in a word, the structure was severely shaken, showing a tendency toward a dish-like form with the concavity downward. It was, however, finally decided to repair it for another trial.

Shot No. 478 (12th September, 1877).—For this experiment no attempt was made to increase the stability of the target by anchorage, as the strain to be delivered was so great that nothing of the kind could be made to hold.

The shock was tremendous, instantly enveloping the target in a broad burst of water, which rose to a height of 75 feet. The four corners, being held by slack hemp cables to ships' anchors, prevented the overturning which had happened to the wooden target under like circumstances. When the water subsided the structure was seen labouring in a great vortex, which sent breakers to the beach a hundred yards distant; but it sunk in a few seconds before the upward boiling had ceased. One corner rested in the mud, thus leaving the plane of the bottom vertical and subjecting the gauges to no pressure from the weight.

The survey after the target was raised indicated plainly that its injuries were irreparable.

IX.—*Considerations as to the Intensity of the Strains.*

The remarkable accordance between the computed and the observed mean pressures for the first six shots shows that no serious loss occurred in consequence of the general motion, *i.e.*, that the system of anchorage had served its purpose perfectly.

When a charge of 100 pounds was placed *under the edge* of the target, even at the considerable distance of 30 feet, the loss becomes apparent; and when this range was reduced to 20 feet, not less than 30 per cent. of the whole intensity of the blow was absorbed in the recoil, notwithstanding the heavy chain anchorage.

When a charge of 200 pounds was placed 30 feet centrally under the target, thus developing the resisting power of the whole sixteen anchors, instead of one-half of them, as before, the loss was reduced to about 7 per cent.; but even this fraction was sufficient to snap every mooring except one. Remembering that these moorings consisted of $\frac{7}{8}$-inch chain cables, attached at each end to a 1,000-pound anchor buried in mud, and strained by a strong tidal lift, the enormous force thus diverted from rupturing the target is evident.

In the last shot, when no anchorage was attempted, 200 pounds, placed centrally 10 feet under the target, expended 64 per cent. of its developed intensity of action in giving motion, and only 36 per cent. in effecting rupture; thus exhibiting the immense advantage, to the defence, of the great weight of modern ships-of-war.

The actual destructive strains upon the target, of course, are measured by the registered and not by the computed mean pressures. Hence, it appears that when this quantity equals about 1,500 pounds per square inch, the blow will buckle the outer plating and be decidedly injurious to the ship, although not seriously damaging; when it equals 3,500 pounds, the shock will be severe upon the engines, movable articles, &c., but will cause no dangerous leak; and finally, when it equals 6,500 pounds, a large hole and a bad leak will be produced. This will be much worse than that caused in the target, because the effective stiffening due to the gauge pipes will be wanting, and also because the quality of iron in the structure was greatly superior to that used in ordinary ship-building.

The following reports of experiments are taken from "Information Series," published by the U.S. Navy Department:—

X.—*The "Resistance" Experiments.*

In September, October, and November, 1886, and June, 1887, some torpedo experiments were carried on against the *Resistance*, to test the efficiency of net protection, and the destructive effect of gun-cotton on an iron hull not so protected.

The *Resistance* was launched in 1861, and was constructed on a different system from that now in vogue. Her load displacement is 6,270 tons, being a little less at the time of the experiment; armour 4½ inches thick in a belt from 4 feet under water to the spar deck; frames spaced 2 feet; skin plating ⅞-inch iron; no double bottom.

The first experiment on September 21 was in the explosion of 61 pounds of gun-cotton against a Bullivant net hung at 30 feet from the side; it resulted in the tearing of the net, the swifter, however, being left intact and the booms uninjured, though the heel of one was unshipped.

In the second experiment (September 22) a 16-inch Whitehead, carrying 91 pounds of gun-cotton, was fired against the net hung in the same position, with the result of tearing away nearly the whole of the net and splitting one boom about the middle.

In the third experiment (September 24) the net was only 15 feet from the ship's side, and a charge of 61 pounds of gun-cotton was exploded in contact; a sea-cock was broken by the concussion, causing a leak.

On October 18 another 16-inch Whitehead was fired, its charge of 91 pounds exploding on impact with the net, which was hung at 25 feet from the side. A rent of 15 feet was torn the entire depth of the net and the swifter broken, but the hull sustained no injury.

The concluding experiment for 1886, on November 2, was against the hull itself. The point selected for attack was on the port side abreast a coal-bunker 4 feet 7 inches deep. This was filled with coal and a ½-inch longitudinal water-tight bulkhead was worked 5 feet inside of it, forming a second compartment 5 feet deep. A torpedo-head holding 91 pounds of gun-cotton (wet) was placed in contact and with its axis normal to the hull, 10 feet under water, just at a half-inch thwartship bulkhead and just below one of the numerous longitudinal stringers. At the time of the experiment there was about 6 feet of water under the keel. The ship gave a moderate lurch to starboard, and finally remained fixed with a slight list to port. She did not sink, and was not even docked for several days afterwards.

The effect of the concussion was distributed over an area of about 20 feet in length by 15 in depth, the limits in the latter direction being the armour shelf and the outer bilge-keel. Throughout this surface the skin was bulged in between the frames, none of the latter being broken excepting the two nearest to the point of explosion. Here the longitudinal had been forced in and the metal of the skin torn apart; five plates were slightly cracked vertically. The thwartship bulkhead was considerably torn and rolled up, and the coal-bunker bulkhead was torn with it, admitting water to the inner compartment; but the third skin was intact. The outer bilge keel was started and bent downward and broken in places for about 8 feet. The interior of the vessel gave evidences of a great concussion; bunker plates had been thrown up and struck the deck above; deck stanchions had been lifted in their seats, fire-room plates displaced, skylights unseated, and a signal mast broken off just below the hounds. There being no steam up nor any engines in motion the effect on running machinery was not determined. As it was, the force of the blast was mainly expended in local disruption, and, apart from the moral effect, which it would be difficult to predicate, the fighting efficiency of the ship was not seriously impaired.

On resuming the experiments in 1887, the vessel was fitted with Bullivant nets and 32-feet steel booms, the latter being spaced 45 feet. The wing passage was left empty, and the coal-bunker, which had been worked inside of that, was filled. On the 9th of June an old pattern 16-inch Whitehead, set for 10 feet, was fired against the net on the port side abreast the engine room, from the under-water tube of the Vesuvius, at an approximate range of 50 yards; the charge was said to be reduced to 87 pounds of gun-cotton. The torpedo struck the net in the middle, immediately under a boom; no damage ensued to either boom or hull.

On June 10, a charge of 220 pounds of gun-cotton was suspended at a depth of 20 feet from the jackstay of the nets (which are 20 feet deep), 30 feet from the side. When it was exploded the ship was not observed to heel or move; some of the steel booms were bent, but no other damage was done.

On June 14, a 95-pound charge of gun-cotton was exploded in contact with the starboard bilge, at a depth of 20 feet. The double bottom, 2½ feet deep, was empty, and the coal-bunker filled (the conditions being thus reversed from those of last year). The explosion created a sharp, whistling report, in place of the usual dull boom; the ship lifted bodily near the stern, listed gradually to starboard some 8 or 10 degrees, and very slowly sank; coal dust was seen to sweep up from the hold. Accurate knowledge of the result cannot be obtained until the vessel is raised and docked; but from a hasty examination it appears that the inner bottom was dislocated, the bunker compartment was penetrated, water-tight doors and bulkheads had ceased to operate, and water was flowing in from a hundred places.

XI.—*Torpedo Experiments at Toulon.*

In September, 1886, at Toulon, 110-pound charges of dry gun-cotton were detonated at different distances from the side of the *Belliqueuse*, an old wooden iron-clad, to test the efficiency of net protection. At 30 and 25 feet distance no damage was done to the hull; at 23 feet the caulking was driven out of a seam for a length of about 6 feet, but that was presumably due to defective caulking, as at 20 and 17 feet no effect was produced.

XII.—*Torpedo Experiments at Cherbourg,* 1885.

In order to ascertain the effect of explosion of a torpedo upon a modern ship's bottom, the French minister of marine caused a portion of the old floating battery *La Protectrice* to be so fitted with inner bottom, bulkheads, and bunkers as to resemble the corresponding parts of vessels now under construction.

The *Protectrice* was built in 1864, of iron. She has a displacement of 1,287 tons, is armoured with 5½ inches of iron, and has two horizontal engines, driving twin screws.

That part of the hull upon which the experiment was to be made was fitted with a double bottom and a longitudinal bulkhead, the latter about six feet inside the outer skin. Inside this bulkhead another was placed for the purpose of preventing the admission of water to the engine or boiler rooms. The outer skin of the *Protectrice* is 0·51 inch thick. The inner skin 0·35, and the bulkhead 0·31 inch thick, were fitted for the experiment. (The bottom skin of a modern French armour-clad is about 0·70-inch iron plate.) The spaces between skins and bulkheads were empty.

The vessel was moored in the port of Cherbourg, about 900 yards from, and heading toward, the shore. The depth of water under the keel at high water was about 2 or 3 feet. Steam was raised upon the main boilers, and the engines were started before making the experiment. The fires and steam were so regulated that they might continue to run uniformly for some minutes. Two small propellers raised above the hull, in connection with the engines, indicated their action.

For purposes of economy a torpedo containing 51 pounds of gun-cotton, with 33 per cent. of water, was fixed to the bottom of the ship, 8·2 feet below the water-line, and abreast the boilers and engines, so that its explosion might represent in all respects that of a Whitehead torpedo upon striking a vessel in this vulnerable part. The charge used was thought to be the equivalent of 37·5 pounds of dry gun-cotton, and was adopted in view of the thin plating of the *Protectrice*, so that the effect upon it might be the same as that of the full charge of a Whitehead, 61·6 pounds, upon the plating of a modern armour-clad.

At 9 o'clock the ship was abandoned and the torpedo exploded. A column of water 22 yards high was thrown up on the side of the vessel, which gradually heeled to about 6 or 8 degrees. The regular motion of the indicators showed the engines to have suffered no serious derangement during the ten minutes following the explosion. After this time had elapsed the observers returned on board, and the engines continued to move for some minutes longer, when they were stopped and the ship hauled ashore. Up to the moment of thus touching the bottom no indication of the vessel sinking was apparent.

At low water the ship was left high and dry, so that an examination of the hole caused by the explosion could be made. Its surface measured about 55 square feet, of a generally regular form (11·5 feet long by 4·6 feet high), with ragged edges, extending from the bilge upwards. The inner bottom skin was broken in, and many angle-irons were bent; but the longitudinal bulkhead (virtually the third skin, with which modern vessels are now built) is said to have withstood the explosion, although it was slightly cracked and two of its rivets were stripped.

Four live sheep were on board at the time of the explosion. They were apparently uninjured, save by a wetting from the column of water.

The vessel will be docked and a careful examination made. From the cursory inspection, the engines have received no injury, and the damage received is local.

Description of the Lay or Wood-Haight Torpedo.

This torpedo is shown at Pl. LVIII., where Figs. 1 and 2 are longitudinal vertical sections of the torpedo and float; Fig. 3 a plan of M^1; and Fig. 4, enlarged vertical section of M^1.

At Pl. LXXII., Fig. 2, is shown a general view of this *Wood-Haight* torpedo, and which is similar in appearance to the *Patrick* torpedo described at page 247.

The torpedo is circular as to cross-section, and it tapers toward the bow and stern on lines preferably curved from end to end of the torpedo, the ends being sharply pointed, and the hull is made of any suitable material, copper being preferred. The interior of the torpedo is divided by suitable bulk-heads into a number of chambers or compartments, viz., *A* the bow compartment, or magazine which contains the charge of explosive material or compound; *B* the next chamber in order towards the stern, which contains a local battery for firing the charge, a safety device in this battery circuit that prevents the accidental firing of the charge, the valves for starting and stopping the engine, and the electrical devices for operating the valves; *C* the next compartment which contains a gas-heating and expanding chamber;—*D* which contains the storage reservoir of compressed, liquefied carbonic-acid gas; *E* another gas-heating and expanding chamber; *F* the cable chamber which contains the coil of insulated wire by means of which the torpedo is held and guided from the firing point; and *G* which contains the engine, the steering device and the electrical apparatus for controlling the movements of the rudder.

The motive power used in this torpedo is a gas stored in a liquid form under great pressure, in the flask or reservoir D^1 and from there the liquid is conducted by pipes through heating and expanding chambers to the engine G^1 that drives the propeller G^2 that is fast to the hollow shaft G^3 which extends beyond the stern of the torpedo in line with the axis.

The liquid is conveyed from the flask D^1 by the pipe D^2 through the strainer d to the throttle valve d^1; thence to the coil in the heating and expanding chamber C^1; thence back through a pipe passing through the open pipe D^4 and through the flask to the coil of pipe in the other heating chamber E^1, where it is further expanded into gaseous form and finally into the induct or supply pipes of the engine G^1.

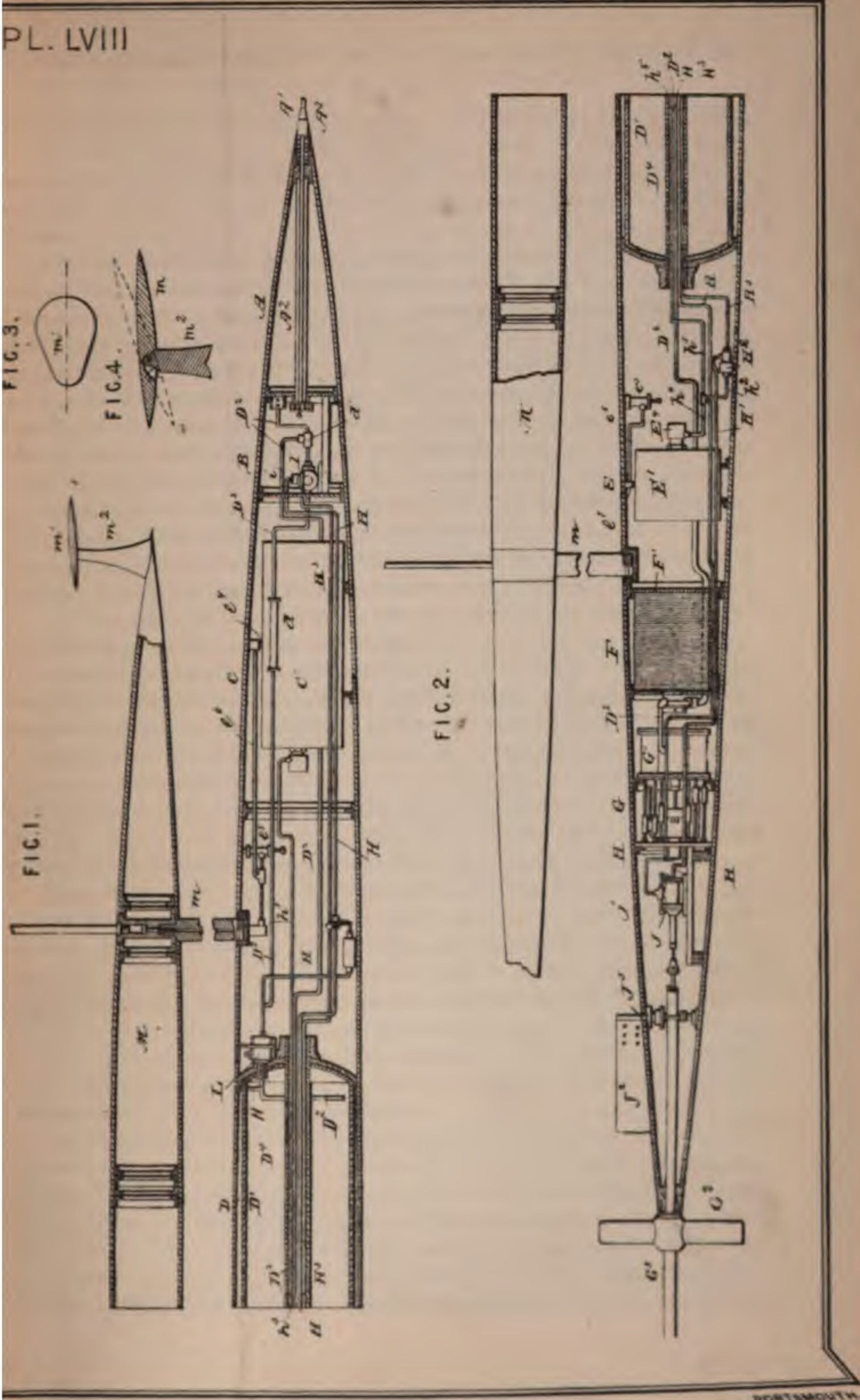
The engine consists of a series of cylinders grouped about a central hollow shaft G^3 that bears a cam block, having in its surface a curved cam groove. Into this cam groove pins project and bear against the faces of the cam in such manner and position that the rectilinear reciprocating movement of the several pistons and rods is translated into a continued rotation of the cam block, and of the hollow shaft that bears the propeller.

The gas in the upper part of the reservoir or flask D^1 is conveyed by the pipe H to the throttle controlling cylinder I and also to the steering cylinder J, its supply to the former being controlled by a slide valve i connected by bell crank levers to the armature of an electro-magnet and to the cylinder J by a slide valve j connected by similar bell crank levers to the armature of another electro-magnet.

The gas-heating and expanding chambers and their contained mechanism are similar in all respects, and a description of the chamber E^1

THE LAY-HAIGHT CONTROLLED TORPEDO.

PL. LVIII



and its mechanism will apply to both. The chamber E^1 is a closed cylinder of any suitable metal, as copper, made in two or more parts bolted or otherwise fastened together, with openings through the end walls for the passage of the several pipes of the gas circulating system.

The pipe D^2 is formed into a coil within the chamber E^1 in any desired and convenient form, and is more or less immersed in the liquid, sulphuric acid and water, that forms part of the gas-heating mixture. To the wall of the chamber is attached a lime tube formed in two or more segments hinged together, so that when opened its contents will be dropped into the solution in the chamber. The parts of the tube are held closed by a bolt that has several arms each passing through the holes in two or more lugs that are fast to each of the body parts of the tube, and the latter is sprung open, when the bolt is withdrawn, by the recoil of flat springs that are placed within the tube and curved by the closing of the parts of the latter. This tube is filled with lime broken into pieces of convenient size to aid its ready mixing with the acid solution, and the tube is opened to dump the lime by the pressure of the gas from the tube h^4 upon a piston that is movable in the cylinder E^4 fast to the end wall of the chamber E^1, the piston being fast to the outer end of the bolt.

In order to reduce the pressure of the gas formed by the heating mixture the chambers C^1 and E^1 are provided with a safety valve e^5 on the pipe e^6 leading from the opening e^7 in the wall of the chamber, and having a vent through the shell of the torpedo in any convenient place, as through the brace and standard m of the float. This safety valve is of ordinary construction, except as to the packing which is formed by a volume of oil held in an extension of the valve body, and in this oil the valve stem and spring are submerged, thus preventing corrosion of the spring.

The cable which forms the connection between the torpedo and the station from which it is directed is made up of two insulated wires, one serving as the conductor, for operating the valves of the starting and stopping device, and the other being used to operate the steering or guiding devices. One of these wires is connected to a binding post of a relay which is connected to the steering electro-magnet, and the other end of this wire is connected to a pole changer at the station, so that the armature of this magnet can be moved to either pole at will by the movement of a key at the pole changer.

As the armature tilts to one side the slide valve j of the cylinder J is moved so as to admit the motive power (the compressed gas) into the end of the cylinder through a port, and this forces the piston forward, moving the rudder J^2 to starboard by means of the connecting rod that is pivoted to one arm of the frame of the rudder post J^5. This post is stepped in a shoe fast to the bottom of the torpedo, is widened in the shape of a frame to avoid the hollow shaft G^3, projects through the hull at an opening closely protected against leakage by an ordinary packing box, and supports the rudder upon the upper side of the torpedo.

As soon as this valve *j* is opened, the gas not only flows into the cylinder, but passes from it by means of the pipe H^1 that leads to the bolt tripping cylinders of the lime tubes of the several gas-heating chambers, and by its pressure at once draws the bolts and dumps the lime.

By this arrangement of the parts this important operation is performed at will and quickly, and is a feature of this invention.

At a convenient point in the line of this pipe H^1 is placed a cut-off valve H^2 to prevent the flow of gas into the heating chambers every time that the rudder may be moved to starboard in handling the torpedo.

By a movement of the key at the pole changer the current is broken and the armature is released, which allows the slide valve of the steering cylinder to move to the central position under the pull of a spring so coiled about the extension of the valve stem and so seated as to be compressed by the movement of the valve to either side of the centre. At the same time the rudder is brought to a central position or "steady" by the recoil of a spiral spring that is coiled about the piston rod, and is seated between a collar on the rod and the cap on the tube projecting from the cylinder head, and the piston is also returned to a central position in the cylinder.

The extent of play of the rudder is regulated by devices within the cylinder *J*. The piston rod extends a short distance through the piston and bears two nuts that are movable on a thread cut on the piston rod and can be set and clamped at varying distances from its face. A recess is cut in the back head of the cylinder large enough to admit the end of the piston rod but not the nuts, and the distance the piston will move towards the back head is clearly determined by the position of the set nuts.

A similar pair of set nuts are adjustable on the rod on the front side of the piston, and a corresponding recess is formed in the back of the front head of the cylinder; by these latter nuts the forward movement of the piston is determined.

By moving the key so as to send a current in the reverse direction, the armature, valve, piston, and connected parts will be so moved as to throw the rudder to port.

Before this starboard movement is effected the armature of the starting magnet is so moved by a current sent through the second wire from the station as to move the slide valve *i* which opens the throttle valve d^1 in the supply pipe D^2 from the reservoir to the heating chambers. This movement allows the gas from the upper part of the reservoir to pass in the tube *H* to the cylinder *I* and through that and into the tube H^3 by which it is conveyed to the cut-off valve H^2.

In order to allow the liquid to be forced into the pipe D^2 and the gas from the reservoir into the pipe *H* the cocks in the plug *L* must first be opened, and this is done by hand before the torpedo is launched at the station or started from it.

The firing bar or pin A^1 projects from the pointed bow of the torpedo a short distance, and it has a limited sliding movement in a tube A^2 that extends completely through the magazine from the extreme bow to and through the closed bulkhead that separates the magazine from the next compartment. This pin is held out by a stout spring A^3 and when it is pushed inward, as by striking an object in motion, the rear end of the pin is thrust between the two terminal points and connects them. These points are in the circuit of the local battery. In the firing circuit there is a specially arranged safety device consisting of a second break in the circuit, which is only closed when the engine is actually running.

When the engine is in operation the pushing in of the firing pin completes the local battery circuit and fires the fuse, thus exploding the charge, but when the engine has stopped, the safety break is made in the circuit and the torpedo can be handled with no danger of the accidental explosion of the charge.

In order to protect the torpedo from injury from projectiles that may be fired at it, it is submerged a short distance (about three feet), and is held at the desired depth by means of the float M that is secured to standards or braces m rising from the upper side of the torpedo. This float is similar in shape to the torpedo, is somewhat longer than it, and is filled with cork, cellulose, or a great number of inflated rubber bags which are very buoyant and will not be washed out of the float even when the latter is pierced and riddled with balls. The usual guide rods project from the upper side of the float and bear flags to indicate its position and direction.

The cable is payed out from the cable chamber through the hollow propeller shaft in the ordinary manner as the torpedo moves away from the station or starting point.

The float overhangs the stern of the torpedo and the propeller and thus prevents the latter from pulling the stern down and lifting the bow out of water, and the drag m^1 fast to the bow of the float on the end of the standard m^2 aids in preventing the boat from diving, the object being to ensure a horizontal position and motion of the torpedo in action in the water. The long float serves to support the torpedo with the charges of explosive at a depth below the surface of the water that will make its explosion surely effective.

The firing pin or bolt is shut out from the magazine chamber, and the advantage of this is that the charge can be packed well into the bow of the torpedo without danger of accidental explosion which would be caused by such contact with the pin, if uncovered, and the wires, as would form an electrical connection and ignite the fuse.

A SYNOPSIS OF THE PRINCIPAL EVENTS CONNECTED WITH THE HISTORY OF THE TORPEDO.

Date.	Operator, &c.	Event.	Place.	REMARKS.
1585.	Italian Engineer, Zambelli.	Attack on a bridge formed over the Scheldt.	Antwerp.	Bridge completely destroyed. Vessels, each carrying a heavily charged magazine, fired by clockwork, were carried by the stream against the bridge.
1624.	Cornelius van Drebbel.	Experiments with diving boat.	River Thames, England.	The earliest record of a submarine boat.
1730.	Desaguliers.	Experiment with rocket torpedoes.	..	This French scientist is said to have destroyed several boats by rockets fired under water.
1774.	Day.	Experiments with diving boat.	Plymouth, England.	In the second trial this boat was lost with the inventor.
1775.	Captain D. Bushnell.	Numerous small experiments with gunpowder charges.	America.	By which he proved that a charge of gunpowder could be fired under water.
1776.	"	Attack on the English frigate H.M.S. *Eagle* by his submarine torpedo boat.	New York.	Boat managed by Sergeant E. Lee. Attack failed, owing to his inexperience in manipulating this novel kind of craft.
1777.	"	Attack on the English man-of-war H.M.S. *Cerberus* by his drifting torpedoes.	New London.	Drifting torpedoes employed. Crew of a prize schooner astern of the *Cerberus* hauled one of the torpedoes on board, which exploded, killing 3 men and destroying a boat.
1777.	"	Attack on English ships by numerous floating torpedoes. Known by the name of "Battle of Kegs."	..	This failed, owing to the ships having previously hauled into dock to avoid the ice, but it created a great amount of confusion and alarm among the crews of the vessels.
1797.	Reveroni Saint Cyr.	Earliest record of submarine gun.	France.	This Frenchman proposed a sort of Catamarran with 48-pr. carronade to be towed underneath a vessel.
1797.	R. Fulton.	Experiments with torpedoes on the Seine.	"	These first attempts were generally failures.
July 3, 1801.	"	Experiments with his submarine boat named the *Nautilus*.	Brest, France.	These experiments were successful in so far as proving that with such a boat he could descend to any given depth and reascend to the surface at will, and that he could remain below for a considerable time.

August 1801.	"	Attempted to sink a small vessel by means of one of his torpedoes.	"	Completely successful. This is the first vessel known to be destroyed by means of a torpedo. Charge of submarine mine 20 lbs. gunpowder.
1801.	"	Attempted to destroy one of the English channel fleet by means of his drifting torpedoes.	Off Boulogne, France.	Owing to the ship altering her position at the moment of setting the torpedo adrift, this attack failed.
Oct. 3, 1804.	"	Catamaran expedition under Lord Keith to destroy the French fleet.	Boulogne, France.	Failed, owing to a mistake in the construction of the torpedoes. The mines exploded, but did no damage to the French Ships.
Oct. 1805.	"	Similar expedition.	"	Similar failure, owing to causes above-mentioned.
Oct. 15, 1805.	"	Attempted to destroy a brig *Dorothea* with his drifting torpedoes.	Dover, England.	The brig was completely demolished. Two torpedoes employed, each charged with 180 lbs. gunpowder and fired by clockwork.
July 20, 1807.	"	Experiment on a large hulk brig.	New York, America.	Finally successful, several attempts being necessary, owing to faulty construction.
Oct. 1810.	"	Attack on the U.S. sloop *Argus* for finally testing the efficacy of his torpedo schemes.	New York.	Failed, owing to the very ingenious though elaborate defence of the vessel, carried out under the directions of Commodore Rodgers.
1812.	Mr. Mix.	Attack on the English frigate H.M.S. *Plantagenet* with his drifting torpedoes.	Lynn, Haven Bay, America.	Complete failure, though six different attempts were made.
June 15, 1813.	"	Attack on H.M.S. *Ramilies* by blowing up a schooner alongside.	New York.	An utter failure.
1814.	R. Fulton.	Experiments with submarine guns.	"	Penetrated a bulkhead equal in thickness to the bottom of a first-class ship at a distance of 12 to 15 feet.
1820.	Captain Johnson.	Experiment with a submarine boat carrying a torpedo on its back.	Moulsford, Berks, England.	Idea was to fasten the torpedo by means of screws to the bottom of the hostile vessel. Trial proved successful, but the English government refused to sanction the project as being too diabolical.
July 4, 1829.	Colonel Samuel Colt.	Experiment on a raft with his submarine battery.	Ware Pond, America.	Successful.
1839.	General Paisley, R.E.	Destruction of the wreck of the *Royal George* by submarine mines.	Portsmouth, England.	He is stated to have employed galvanic firing to explode the mines.

A SYNOPSIS OF THE PRINCIPAL EVENTS CONNECTED WITH THE HISTORY OF THE TORPEDO—*continued.*

Date.	Operator, &c.	Event.	Place.	REMARKS.
1840.	Captain Warner.	Experiment on the *John O'Gaunt.*	England.	Successful. Details not known.
June 4, 1842.	Colonel S. Colt.	Experiment to explode a submarine mine by electricity.	New York.	Successful. The operator was at a great distance from the torpedo.
July 4, 1842.	„	Experiment on the U.S. gun-boat *Boxer* with electric submarine mines.	Castle Garden, New York.	Successful. The operator was on board U.S. man-of-war at some distance from the place where the explosion occurred.
Aug. 20, 1842.	„	Similar experiment on a schooner.	Potomac River, America.	Successful, the operator being stationed at a distance of 5 miles from where the mine was placed.
Oct. 18, 1842.	„	Similar experiment on the brig *Volta*, 300 tons.	New York.	Successful. The operator being on board the revenue cutter *Ewing*, at a considerable distance from the scene of the explosion.
April 13, 1843.	„	Experiment to destroy a vessel of 500 tons *under weigh* by electric submarine mines.	Potomac River, America.	Successful. The vessel was, at the time of the explosion, sailing at the rate of 5 knots per hour, and to prevent the possibility of any collusion between the operator and crew, they left the ship a few moments before the catastrophe. Operator 5 miles distant. Probably several mines were placed in the form of a circle.
July, 1844.	Captain Warner.	Experiment with his invisible shell, on a barque of 450 tons.	Brighton, England.	The vessel completely destroyed.
Jan. 1, 1845.	Colonel S. Colt.	Experiment with an electric submarine mine.	New York.	Successful. The operator being at a distance of 40 miles from where the explosion took place.
1846.	Professor Schonbein.	Discovered the explosive agent "gun-cotton."	..	Brought into use for military purposes about 1863, by Professor Abel.
1846.	Sobrero.	Discovered the explosive agent nitro-glycerine.	..	Brought into use about 1863, for blasting purposes by M. Alfred Nobel, a Swede.
1854.	Russians.	Attempted destruction of the English men-of-war *Merlin* and *Firefly*, by stationary submarine mines.	Cronstadt.	Several torpedoes were exploded near these ships, but with no other results than a wetting to some of their men.

Feb. 18, 1862.	Confederates.	Federal gunboats attempting to force the Savannah river.	America.	Considerably delayed, caused by the submarine mines, but no actual damage done. This was their first appearance in a practical form during the civil war.
Dec. 12, 1862.	"	Destruction of the Federal iron-clad *Cairo*, by stationary torpedoes.	Yazoo River, America.	Two torpedoes exploded under her; vessel much shattered, and sunk in 12 minutes. First vessel destroyed in this war.
Feb. 28, 1863.	"	The Federal monitor *Montauk*, severely damaged by a submarine mine.	Ogeechee River, Georgia.	She was saved from sinking by being run on the mud, thus enabling the hole to be temporarily closed, and the vessel taken to Port Royal.
July 22, 1863.	"	The Federal ironclad gunboat *Baron de Kalb*, sunk by a submarine mine.	Yazoo River.	The vessel went down in 15 minutes. As she was sinking a second torpedo exploded under her stern. No lives were lost.
Aug. 8, 1863.	"	The Federal gunboat *Commodore Barney* severely damaged.	James River.	The ship was, at the time of the explosion, steaming 9 knots, and ran into it, losing 20 men, and being somewhat severely damaged. It was an electric submarine mine charged with 1750 lbs. gunpowder.
Sept. 1863.	"	The U.S. transport *John Farrow*, seriously injured.	"	By a submarine mine.
Oct. 5, 1863.	"	Boat torpedo attack on the Federal ship *Ironsides*.	Off Charleston.	Seriously injured. It was made by a boat armed with a spar torpedo with 60 lbs. gunpowder.
1863.	"	Confederate steamers *Marion* and *Ettiwa* destroyed by their own mines.	"	Blown up accidentally when planting mines.
1863.	"	Confederate flag of truce boat *Shultz*.	James River.	Flag of truce boat blown up accidentally by a Confederate mine when returning to Richmond with exchanged prisoners of war.
Feb. 17, 1864.	"	Boat torpedo attack on the Federal frigate *Housatonic*.	Charleston.	Successful, the ship being sunk. A submarine boat was employed on this occasion, and owing to her running into the hole made by her torpedo, went down with the ship.
March 6, 1864.	"	Boat torpedo attack on the Federal ship *Memphis*.	North Edisto River, South Carolina.	Failed, owing to the torpedo spar being broken by the vessel's screw.
April 1, 1864.	"	Destruction of the Federal transport *Maple Leaf*.	St. John's River, Florida.	This was effected by a floating torpedo.

A Synopsis of the Principal Events Connected with the History of the Torpedo—*continued.*

Date.	Operator, &c.	Event.	Place.	Remarks.
April 9, 1864.	Confederates.	Boat torpedo attack on the Federal ship *Minnesota.*	James River.	The ship was severely damaged, but not sunk. Spar torpedo, charge 53 lbs. gunpowder.
April 15, 1864.	"	The U.S. armoured ship *Eastport* sunk.	Red River, U.S.	By a submarine mine.
April 19, 1864.	"	Boat torpedo attack on the Federal frigate *Wabash.*	Charleston.	Failed, owing to the boat being discovered.
May 6, 1864.	"	Loss of the *Commodore Jones.*	James River.	Completely demolished by an electric torpedo, 1750 lbs. gunpowder. This part of the river having been previously carefully dragged.
May 9, 1864.	"	The U.S. transport *H. A. Weed* destroyed.	Saint John's River, U.S.	By a submarine mine.
June 19, 1864.	"	The U.S. transport *Alice Wood* destroyed.	"	"
Aug. 5, 1864.	"	Loss of the Federal monitor *Tecumseh.*	Mobile Bay.	This occurred during the Federal attack on the defences of Mobile Bay, the ship disappearing almost instantaneously. The captain and 70 of the crew were killed.
Oct. 27, 1864.	Federals.	Boat torpedo attack on the Confederate ironclad *Albemarle.*	Near Plymouth, America.	The only Federal torpedo success during the war. The boat was armed with the Wood and Lay disconnecting spar torpedo. The ship was sunk.
Nov. 27, 1864.	Confederates.	The U.S. transport *Greyhound* destroyed.	James River, U.S.	By a "Coal" torpedo.
Dec. 8, 1864.	"	The U.S. gun-boat *Narcissus* destroyed.	Mobile Bay.	By a submarine mine.
Dec. 9, 1864.	"	Loss of the Federal steamers *Otsego* and *Bazeby.*	Roanoke River.	The latter vessel was proceeding to the assistance of the former. Both were totally destroyed.
1864.	M. A. Nobel.	Introduction of dynamite.	..	A modified form of the explosive nitro-glycerine.
1864.	Captain Lupuis and Mr. Whitehead.	First series of experiments with the fish torpedo.	Fiume, Austria.	The idea of such a weapon previously known, but not acted on.

Jan. 15, 1865.	Confederates.	Loss of the Federal monitor *Patapsco*.	Charleston.	Completely destroyed by a barrel torpedo, sinking in a few minutes. Sixty-two officers and men drowned.
Feb. 20, 1865.	"	The U.S. gunboat *Osceola* crippled.	Cape Fear River.	By a drifting torpedo.
March 1, 1865.	"	Loss of the Federal steamer *Harvest Moon*.	Near Georgetown.	The place where this catastrophe occurred had been previously swept for torpedoes.
March 4, 1865.	"	The U.S. transport *Thorne* destroyed.	Cape Fear River.	By a submarine mine.
March 12, 1865.	"	The U.S. gunboat *Althea* destroyed.	Blakely River.	"
March 28, 1865.	"	The U.S. monitor *Milwaukee* destroyed.	"	"
March 29, 1865.	"	The U.S. monitor *Osage* destroyed.	"	By a drifting torpedo.
April 1, 1865.	"	The U.S. gunboat *Rodolph* destroyed.	"	By a submarine mine.
April 13, 1865.	"	The U.S. gunboat *Ida* destroyed.	"	"
April 14, 1865.	"	The U.S. gunboat *Sciota* destroyed.	Mobile Bay.	"
May 12, 1865.	"	The U.S. transport *R. B. Hamilton* destroyed.	"	"
June 6, 1865.	"	The U.S. gunboat *Jonquil* injured.	Ashley River.	While raising *frame* torpedoes.
Sept. 2, 1866.	Paraguayans.	Loss of the Brazilian war steamer *Rio Janeiro*.	Currupaity, Paraguay.	Completely destroyed by a stationary torpedo at the bombardment of Currupaity by the Brazilian fleet.
1868.	Mr. Whitehead.	First official trial of the *Whitehead* torpedo.	Fiume, Austria.	Proved successful and resulted in adoption of this torpedo by Austria.
1869.	Captain W. Harvey, R.N.	Introduction of the towing or *Harvey* torpedo.	Russia.	This form of torpedo now generally given up.
1873.	Mr. J. L. Lay, U.S.N.	Introduction of the locomotive controllable torpedo.	America.	
1874.	England.	Adoption of the electric light in the Navy.		
May 29, 1877.	English.	Torpedo attack by H.M.S. *Shah* on the Peruvian ironclad *Huascar*.	..	This is the first *Whitehead* fish torpedo ever fired against an hostile ship. It failed, owing to the *Huascar* being at too great a distance.

A SYNOPSIS OF THE PRINCIPAL EVENTS CONNECTED WITH THE HISTORY OF THE TORPEDO—*continued.*

Date.	Operator, &c.	Event.	Place.	REMARKS.
May 12, 1877.	Russians.	Russian torpedo boat attack on several Turkish ships.	Batoum.	Failed. A Turkish ship was struck by a towing torpedo, but it failed to explode.
May 26, 1877.	"	Russian torpedo boat attack on the Turkish ships *Fettu Islam*, *Duba Saife*, and *Kilidj Ali*.	Matchines, River Danube.	Successful. A Turkish monitor, *Duba Saife*, was sunk.
June 9, 1877.	"	Russian torpedo boat attack on the Turkish ironclads *Feteh Bulend*, *Moocardemikhair*, and *Idglalieh*.	Sulina, mouth of the Danube.	Failed. The Russian torpedo boat No. 1 was sunk, and her commander, Lieutenant Poutschin, with his crew, taken prisoner. The attack was made by six boats.
June 20, 1877.	"	Turkish monitor attacked by the Russian spar torpedo boat *Choutka*.	Rutschuk, on the Danube.	Failed. The officer in command of the boat being severely wounded, and the torpedo wires cut. This attack was made in the daytime.
June 23, 1877.	"	Two Russian torpedo boats attacked a Turkish monitor.	Mouth of the Aluta, Danube.	Failed, owing to the spirited defence on the part of the Turks. Another day affair.
Aug. 22, 1877.	"	The Turkish ironclad *Assari Shefket* attacked by four Russian torpedo boats.	Soukoum Kaleh.	Failed. The captain of the *Assari Shefket* had placed guard boats in advance of his ship, by which he was warned of the approach of the torpedo boats, and so enabled to foil the attack by a well-directed hot fire.
Oct. 10, 1877.	"	Loss of Turkish gunboat *Suna* at the Russian attack on Sulina.	Sulina.	The gunboat was sunk by striking an electro-contact mine, placed by the Russians about ¾ mile above the Turkish defences. About fifteen officers and men killed and wounded.
Dec. 27, 1877.	"	Turkish squadron attacked by four Russian torpedo boats, two being armed with the Whitehead fish torpedo.	Batoum.	Failed. The Russians fired two Whitehead fish torpedoes (the first attack of this nature during the war), both of which were picked up by the Turks.
Jan. 25, 1878.	"	Attack on Turkish ships by two Russian torpedo boats, armed with the Whitehead fish torpedo.	"	Successful. A Turkish revenue steamer on guard being sunk. Final torpedo attack made in the Russo-Turkish war (1877-78).

10 April, 1880.	Chilians.	Attack on Peruvian corvette *Union* by torpedo boat *Guacolda*.	Bay of Callao.	Failed, owing to one torpedo spar being broken off in a collision with fishing boat, while the other was fired in contact with the boom protection round the *Union*.
23 April, 1880.	"	The *Janequeo* (Yarrow) and *Guacolda*, Chilian torpedo boats, attack Peruvian decked steam launch.	"	Failed. The spar torpedo of the "Janequeo" was fired (electrically) prematurely, causing only a severe shaking to the launch.
May, 1880.	Peruvians.	Attempt to destroy Chilian blockading ships.	Bequeron Channel, Callao.	Failed. This attempt was made with McEvoy drifting torpedoes. Discovered by Chilian guard ship and destroyed.
June, 1880.	Chilians.	Attack on three large Peruvian guard boats by the *Janequeo* and *Guacolda*.	Bay of Callao.	Successful. One Peruvian boat and the Chilian torpedo boat *Janequeo* (Yarrow, 22 knots) sunk by the explosion of the latter's torpedo. Probably fired between the two boats.
July 3, 1880.	Peruvians.	Destruction of the Chilian transport *Loa*.	"	Successful. Effected by means of a coasting vessel set adrift carrying provisions and a box with 300 lbs. of dynamite. This vessel was taken alongside the *Loa* and exploded while being unloaded. The Captain and some 100 men of the *Loa* perished.
Oct. 13, 1880.	"	Attempt to destroy Chilian ironclads.	San Lorenzo anchorage.	Failed. In this case a light framework enclosing 70 barrels of powder with a clockwork firing arrangement was secured under a lighter and moored to the usual anchorage of the Chilian ironclad *Cochrane*; the lighter, however, drifted out of position, and was observed by the *Cochrane*. It exploded at the time arranged for, but without effecting any harm to the enemy.
Dec. 6, 1880.	Chilians.	Torpedo boat attack on the Peruvian gunboat *Arno*.	Bay of Callao.	Failed, owing to escape of the *Arno*. Three torpedo boats attacked, the *Frezia*, *Guacolda*, and a Thornycroft. *Frezia* was hit by a shell which passed through her stern and sunk her, owing to being badly put together. She was raised, and in working order again by the end of the month.

A Synopsis of the Principal Events Connected with the History of the Torpedo—*continued.*

Date.	Operator, &c.	Event.	Place.	Remarks.
Jan. 3, 1881.	Peruvians.	Attempt to destroy Chilian ironclads by a "Herreschoff" torpedo boat.	Off Ancon.	Failed, as the ironclads could not be discovered. *Supposed* that the "Herreschoff" boat was towing two "Lay" torpedoes.
Jan. 4, 1881.	Chilians.	Attack on the Peruvian "Herreschoff" boat by Chilian corvette *O'Higgins*, and the torpedo boat *Frezia.*	Ancona.	Successful. The "Lay" torpedoes are supposed to have been sunk. The "Herreschoff" was run on shore and deserted, and was soon after battered out of shape by the guns of the *O'Higgins.*
Aug. 23 1884.	French.	Destruction of the Chinese corvette *Yung-Woo* by spar torpedo boat.	Foochow, China.	This event occurred during the bombardment of the arsenal and destruction of the Chinese fleet at Foochow.
Feb. 15, 1885.	"	Destruction of the Chinese frigate *Yu-Yuen* by two spar torpedo boats.	Sheipu, China.	The frigate was sunk whilst lying at anchor, and supported by shore batteries. One man of the first attacking boat only was killed, though both boats were some time under fire.

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LONDON: PRINTED BY WILLIAM CLOWES AND SONS (LIMITED), STAMFORD STREET AND CHARING CROSS.